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ORIGINAL ARTICLES.

I.—On a New Specimen of the Liassic Pachycormid Fish *Saurostomus esocinus*, Agassiz.

By A. Smith Woodward, LL.D., F.R.S., Pres. Geol. Soc.

(PLATE II.)

ALTHOUGH the Pachycormid fish *Saurostomus esocinus* was known only by part of a lower jaw from the Upper Lias of Baden when it was first named by Agassiz, its principal characters have since been revealed by many incomplete specimens from the Upper Lias of Würtemberg, France, and Yorkshire, and by a well-preserved fish from Ilminster, Somersetshire, in the Charles Moore Collection, Bath Museum.[1] The internal skeleton of the trunk and the fins, however, have not hitherto been so well seen as in a nearly complete fish from the Upper Lias of Würtemberg, prepared by Mr. Bernhard Hauff and now in the British Museum.

This new specimen, which measures about 1·4 m. in total length, is shown of about one-eighth the natural size in Plate II. The head is deepened by crushing, so that the roof is pushed upwards above and the gular plate downwards below; but it is obviously shorter and wider than that of *Pachycormus*, while the snout is comparatively blunt. The external bones are thin and of fibrous texture, and are thus crushed on the stouter inner elements in a confused mass, but a few features are recognizable. A notch in one bone which seems to be nasal may be regarded as marking the narial opening. The blunt rostral region is shown in front view, with a row of small conical teeth along the oral border as already observed in a Whitby specimen. The large orbit is indicated by an ossified sclerotic in two halves, anterior and posterior. The cheek-plates are obscured by their crushing on the mandibular suspensorium and pterygo-palatine bones; but it is clear that although the hyomandibular is inclined backwards, the quadrate turns as sharply forwards, so that the mandibular articulation is not far behind the orbit. Below the cheek the long and slender maxilla is conspicuous, a little downwardly curved in its hinder portion, where its upper border is overlapped by a single long and narrow supramaxilla. The maxilla bears the usual large conical teeth in a spaced series, flanked outside by a close series of comparatively minute teeth, as in *Hypsocormus*. A cluster of rather large teeth, of the palatine or other inner element, is also seen between the maxilla and displaced premaxilla. In the mandible the

[1] For references to literature see Catal. Foss. Fishes Brit. Mus., pt. iii, p. 388, 1895; also A. S. Woodward, "Fossil Fishes of the Upper Lias of Whitby," Proc. Yorks. Geol. and Polyt. Soc., vol. xiii, p. 158, pl. xx, 1896.

angular bone is relatively small, and the dentary is as originally described by Agassiz. The lower teeth of the spaced series are slightly larger than those of the upper jaw, but are similarly flanked outside by clustered minute teeth. All the teeth are conical, a little incurved at the apex, covered with smooth enamel, and vertically fluted at the base. The preoperculum, operculum, and suboperculum are vaguely seen, of the characteristic shape. Behind the large gular plate there are also traces of the branchiostegal rays.

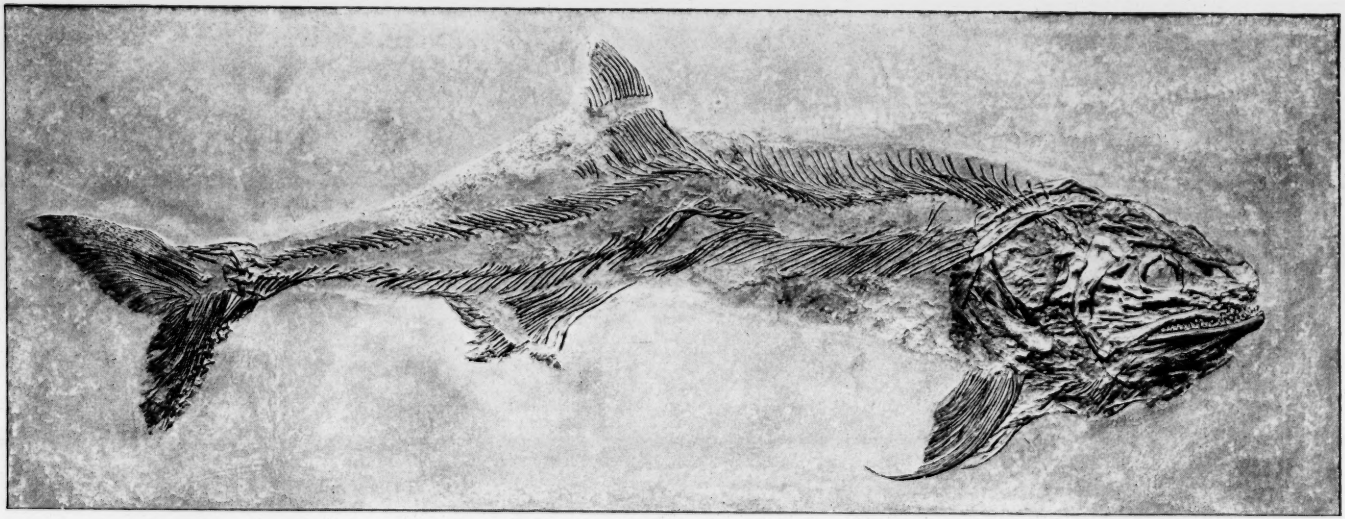
The trunk is distorted as usual, especially just in front of the dorsal and anal fins, which are thus separated a little from their supports. The vacant space for the notochord is widened by this distortion, but most of the arches above and below are well preserved. The total number of vertebral arches is about 110, of which 50 may be assigned to the abdominal region. The ribs are comparatively short and slender, while the neural arches of the abdominal region bear gently curved spines, each forming an irregular node at its fused lower end and tending to slight expansion at its upper or distal end. In the caudal region the simple neural and hæmal arches are nearly symmetrical above and below the notochordal space, and sharply inclined backwards. Within the base of the tail six or seven hæmals become relatively stout, and the last hæmal forms the fan-shaped bone which is so characteristic of the Pachycormidæ.

In the pectoral arch the two supraclavicles are well seen, relatively large, long and narrow, straight, and of conspicuously fibrous texture. The clavicle is obscured, but behind it there are traces of the usual thin and large postclavicular scales. The right pectoral fin is specially well preserved, with at least twenty rays, which do not appear to be transversely articulated but become very finely divided distally. The fourth or fifth and longest ray is gently curved and much longer than the others, which rapidly shorten backwards.[1] There is no trace of pelvic fins. The supports of the dorsal and anal fins, which are well preserved though displaced, are remarkable for their great length. Not less than twenty-five or twenty-six of these supports are shown in each fin, all expanded at the end for articulation with the fin-rays. The dorsal fin must have been almost completely in advance of the anal, and the fragmentary remains show that it was elevated in front, comparatively low behind. The anal fin is altogether less elevated, and the articulations of its rays are shown to have been distant. The rays of the powerful forked caudal fin are also articulated only at distant intervals, but are very finely subdivided distally.

Nearly all the scales have been removed from the fossil, but a scattered patch behind the dorsal fin shows that they are small and thin, with some traces of a very fine tuberculation. There are vague remains of the enlarged scale at the origin of the anal fin. Indications of digested food are also seen in the abdominal region.

The most interesting feature of this new specimen of *Saurostomus* is the remarkable elongation of the anterior pectoral fin-ray, which

[1] The pectoral fin from Whitby figured in Proc. Yorks. Geol. and Polyt. Soc., vol. xiii, pl. xx, fig. 2, 1896, thus seems to belong to *Pachycormus*, not to *Saurostomus*.



SAUROSTOMUS ESOCINUS, *Agassiz*.

Upper Lias. Holzmaden.

Nat. size 72 × 69 cm.

suggests its use as a tactile organ. Although such elongation is not uncommon among modern Teleostean fishes, it does not appear to have been observed hitherto among Mesozoic Ganoids. I may also add that some of the bones, such as the supraclavicle and the neural arches fused with their curved spines, are exact miniatures of some of the bones of the gigantic *Leedsia problematica* from the Oxford Clay. They therefore tend to support the opinion that this largest known Mesozoic Ganoid belongs to the Pachycormidæ.

EXPLANATION OF PLATE II.

Saurostomus esocinus, Agassiz; nearly complete fish, about one-eighth natural size. Upper Lias: Holzmaden, Würtemberg. British Museum No. P. 11126. Prepared by Mr. Bernhard Hauff.

II.—On the Punctation of the Shells of *Terebratula*.

By F. G. Percival, B.Sc., F.G.S., Assistant Lecturer in Geology at the University of Manchester.

(PLATE III.)

In 1844 Carpenter [1] divided the fossils then known as *Terebratula* into two groups—a perforate group, having the test covered with minute pores, and an imperforate group (the Rhynchonellids). These perforations (see Plate III) correspond to tubular processes of the mantle.

Sharpe [2] suggested that these cæcal processes of the mantle had a respiratory function; but the shell is covered with a chitinous periostracum which is imperforate. Carpenter considered this might be cellular, allowing water to pass through. Sollas [3] in 1885 suggested that they were sense organs affected by light, since the periostracum is transparent. Morse [4] offers the suggestion that they are organs of general sensibility.

The tubules are not of uniform diameter throughout. The inner half, near the mantle, according to King [5] is narrow, the outer half wider, with a sudden dilation at the 'mouth'. From the mouth a number of fine lines or tubes radiate. It is interesting to note that from the outer lip of each cæcal process a number of fine cilia radiate. Possibly these cilia fit into the radiating tubes (see Morse [4]). The radiating tubes are rarely seen in fossils. An example is shown in Pl. III, Fig. 3.

In some forms, e.g. *T. punctata*, Sow., the punctæ are elongated and slit-like at the outer surface, but have a round cross-section a little farther in. This is well shown in Fig. 5, where part of the outer layer has flaked off.

In *Terebratulina* (Fig. 1) the cæcal tubules branch as they pass outwards, but I have not observed this in any species of *Terebratula*. It would, however, be difficult to recognize in fossil specimens, even if present.

The examination of the punctæ, or external openings of the tubules, was first undertaken with the hope of using their variations as aids in distinguishing species. The punctæ are arranged in rows roughly parallel with the growth-lines. When the apertures are slit-like the long axis of each slit points to the umbo, and this emphasizes the fact that they are also arranged in rows radiating out from the umbo.

Where the shell is smooth one may find either a square or a quincuncial pattern, but this regularity is broken by the subdivision of the rows, both transversely and radially. There is a tendency here and there for the lines to become very irregular, the radial rows 'streaming out' into many branches. This occurs, Mr. J. W. Jackson informs me, particularly along the muscle impressions. In the gerontic stage the transverse lines are no longer in sweeping continuous curves, but are broken up into many little wavelets, and it is very difficult to count them.

With regard to the size of the punctæ, one can distinguish roughly between coarsely and finely punctate shells, but nicer distinctions are unreliable, since the shapes of the individual punctæ depend very largely on the amount of wear the shell has suffered; e.g. in *T. punctata*, Sow., an unworn shell may show long slit-like punctæ, while a more worn test has rounded pores. Usually the punctæ are hollows, but in specimens that have been naturally etched the material filling the punctæ may project beyond the general surface level. Sometimes the 'walls' of each punctation project slightly, forming a small tube-like process. But all these differences may occur in one species, or even in different parts of one individual, and are therefore useless for our purpose.

The only other convenient means of distinction by punctæ is the variation in the number per square millimetre (or 'density'). If the various species have sufficiently different densities this would be a valuable aid in specific determination. It is already so used to some extent.[1]

There is a gradual increase in the density from the umbo outwards to the anterior edge. The following readings are typical—

T. biplicata (Brocchi) (*a*) 93, 111, 115, per sq. mm.
(*b*) 72, 75, 86, 98, per sq. mm.
(*c*) 68, 62, 81, 92, 112, per sq. mm.
(*d*) 49, 54, 67, 90, per sq. mm.
T. aff. *crickleyensis*, S. Buckman, 224, 292, 344, per sq. mm.

In each of the above five examples the first reading was at about 1·5 cm. from the umbo, the other numbers being progressively farther out. Not all of the individuals show such big variations, and this increase is not always regular. Occasionally there will be a decrease in density over a zone a few millimetres wide (see example *c* above). Again, when a strongly marked growth-line intervenes there is usually a sudden change of density. This is to be expected if there is a continuous variation from youth to age, a variation which is maintained even during the period of slow growth or cessation of growth represented by such a strongly marked growth-line. In *T. biplicata* (Brocchi) the rate of increase is more rapid towards the sides than towards the anterior along the median line. This is obviously because the shell is longer than it is broad; hence growth takes place more rapidly at the anterior edge than at

[1] See e.g. F. Blochmann, *Die Brachiopoden der Schwedischen Südpolar-expedition*, Stockholm, 1912, and J. W. Jackson, "The Brachiopoda of the Scottish National Antarctic Expedition": Trans. Roy. Soc. Edin., vol. xlviii, pt. ii, No. 19.

the sides, and one travels over the stages from youth to age more quickly in an oblique direction than along the median line. The variation is negligible along any particular zone of growth parallel to the growth-lines.

It follows from the foregoing that one must always choose some fixed part of the test for the counting. In the earlier work the valves were divided into squares of one centimetre, commencing at the umbo, the lines being painted in water-colour. Readings were taken in the second square, i.e. at between one and two centimetres from the umbo, on the dorsal valve when possible, otherwise on the ventral. The figures for the ventral valve are approximately the same as for the dorsal.

If the density is to be of any value the range for a species must not be very great. But it appeared in one or two cases that there was a rather large variation. Moreover, as previously mentioned, occasionally a sudden change occurred. For example, a specimen of *Microthyris sublagenalis*, Davidson, showed in the first square centimetre a band where the density rose suddenly from 168 to 272 (see Pl. III, Fig. 2). A strong growth-line separated the two readings, but farther out, in the third square from the umbo, the density had fallen to 152. Obviously, if irregular variation like this is at all common there will be a big range for each species, even if we confine our readings to a spot of very small area at a fixed distance from the umbo in each example.

In order to test this large numbers of two species were collected. The first was *T. biplicata* (Brocchi), using the term in Davidson's broad sense, of which 166 examples were obtained from the Manchester Museum collection. All were from one horizon and locality—Lower Chalk, Sewell. There was a fairly wide variation in form, but there was a complete gradation among them. Over 300 specimens of *T. punctata*, Sow., were also collected from a couple of blocks in a Middle Lias quarry at Stathern, Leicestershire. In these specimens the punctæ were usually beautifully preserved and yet difficult to count. Staining did not improve them at all. Most of them had transparent shells with a black matrix inside and filling the punctæ. The matrix showed through the test, and the punctæ were almost invisible against the dark background. On heating the fossils on wire gauze over a Bunsen flame the tests cleaved into myriads of tiny rhombs, giving an opaque white appearance against which the black punctæ showed very distinctly. After heating, the surface was covered with Canada balsam to prevent flaking, but in some cases it was an advantage to let the thin outer layer flake off, as the round cross-section of each punctation in its inner half made a very distinct spot, easy to count.

At first photomicrographs of known magnification were taken, but this was too slow a process. The later work was done by using a long extension camera, giving an image magnified fourteen diameters. A square of 14 millimetres was cut out of a sheet of paper, which was then moved into various positions on the screen. With the aid of a lens several readings were thus taken for each individual, by counting the numbers in the square. These readings

were averaged. In order to keep approximately to the same area in each case a circle was drawn on each specimen.

The range in each of the two species was very great. There is no reason to suppose that they are in any way abnormal. In *T. biplicata* one individual had a density of only 39 per square millimetre, and one was as high as 129. *T. punctata* ranged from 66 to 240. Thus these two species alone cover a great part of the whole range of variation possible for the genus, and the feature must be of extremely little value for purposes of specific distinction. The following tables summarize the results. It was necessary to group the density numbers in tens for two reasons: first, the actual number of individuals was small compared with the great amount of variation, and secondly, certain numbers tended to predominate owing to the method of counting. In order to count accurately from 100 to 200 tiny spots within a square of 14 millimetres one must, if possible, get them arranged in rows parallel with the sides of the square. As a result one often gets, say, eight rows of eight or nine punctæ, and so on; i.e. numbers like 64 (8 × 8), 72 (8 × 9), 81, 90, 100, 121, etc., will unduly predominate. So those individuals with a density of from 41 to 50 were grouped together, and so on.

TABLE I.—*T. punctata*. (See Fig. 1.)

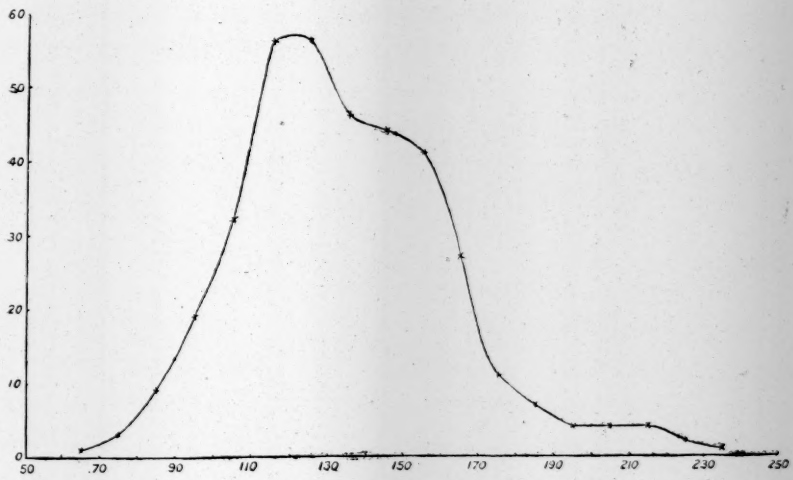
Punctæ per sq. mm.	Nos. of individuals.
61– 70	1
71– 80	3
81– 90	9
91–100	19
101–110	32
111–120	56
121–130	56
131–140	46
141–150	44
151–160	41
161–170	27
171–180	11
181–190	7
191–200	4
201–210	4
211–220	4
221–230	2
231–240	1
Total	367

TABLE II.—*T. biplicata*. (See Fig. 2.)

Punctæ per sq. mm.	Nos. of individuals.
31– 40	1
41– 50	13
51– 60	36
61– 70	43
71– 80	41
81– 90	14
91–100	10
101–110	6
111–120	1
121–130	1
Total	166

The results are shown graphically in Figs. 1 and 2. It will be seen that the curve for *T. biplicata* is a simple variation curve, confirming the fact that only one species was being dealt with, and incidentally supporting Davidson's application of the name to a wide range of forms. The mode occurs at between 60 and 70 per square millimetre. The curve for *T. punctata* shows a fairly pronounced hump a little beyond the mode, which lies between 110 and 130.

FIG. 1.



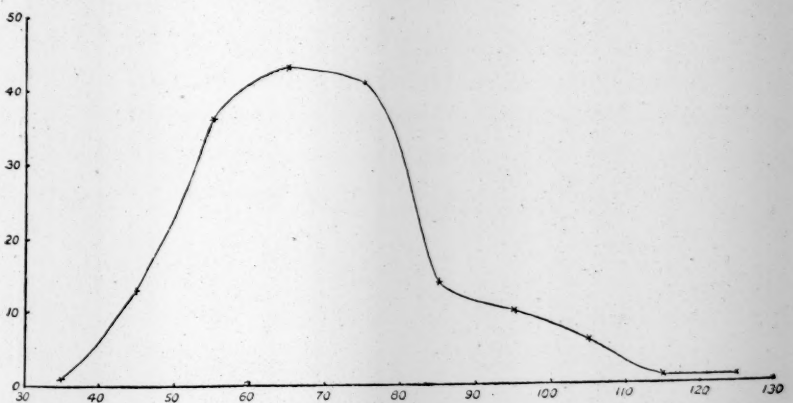


FIG. 2.

FIG. 1.—Curve showing variation in number of punctæ per sq. mm. in 367 individuals of *T. punctata*, Sby. Abscissæ = punctæ per sq. mm. Ordinates = numbers of individuals.

FIG. 2.—Curve showing variation in number of punctæ per sq. mm. in 166 individuals of *T. biplicata*.

This may imply the oncoming of a variation, but possibly it may mean that the mode of the specimens from this locality was a little lower than the mode for the species as a whole. If, for example, the mode for the whole species were 150, and the mode for this particular locality between 110 and 130, one would expect the numbers of individuals with a density of 130 to 150 to be greater than those with density 110 to 90, i.e. the curve would slope down more gently to the right of the mode than to the left.

In conclusion three points may be emphasized: (1) The shapes of the individual punctæ depend to a great extent on the state of preservation of the test, since the shape of the cross-section of a punctation often varies as it passes outwards, from circular to oval or slit-like. (2) There is in general a progressive increase in density from the umbo outwards, which is approximately the same in each valve. This increase is not always regular; occasionally the density will decrease for a while, and at the larger growth-lines there is usually a sudden increase. (3) The amount of variation in a species is so great as to make the density almost valueless as a specific character.

I wish to offer my grateful thanks to Dr. A. Morley Davies, Dr. G. Hickling, and Professor H. H. Swinnerton for the advice and help they have given at various times during the rather tedious work on which this paper is based.

EXPLANATION OF PLATE III.

FIG. 1. *Dyscolia crossei*, Dav. Recent: Japan. Middle of ventral valve photographed from outside, showing branching punctations. The forks point to the umbo. (This is the case in all *Terebratulinæ* I have examined, though Fischer & Œhlert, in describing this species, state that the canals are directed obliquely "d'arrière en avant".) × 48.

,, 2. *Microthyris sublagenalis*, Dav. Bathian: Marquise, Boulonnais. Dorsal valve, less than 1 cm. from umbo, showing a sudden increase of density from 168 to 272 per sq. mm. × 20.

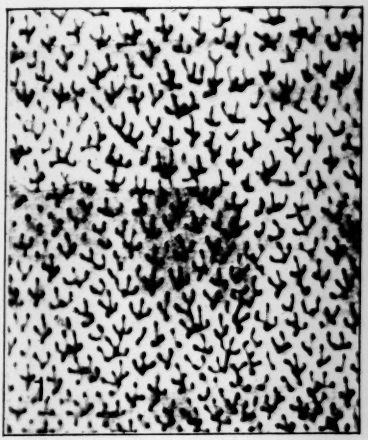
,, 3. *T. punctata*, Sow. Middle Lias: Stathern, Leicestershire. Portion of test showing "radial canals" at outer aperture of each punctation. × 40.

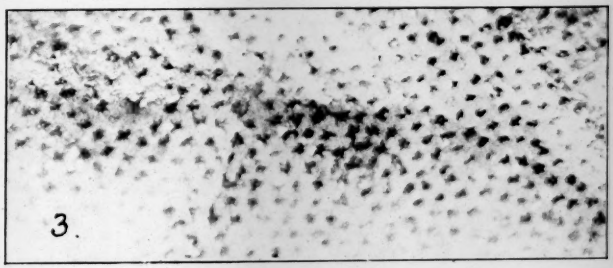
,, 4. *T. punctata*, Sow. Flake of shell by transmitted light, showing punctæ with circular cross-section, changing to slit-shape at the outer surface. × 40.

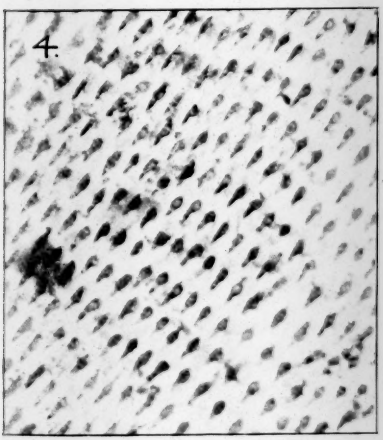
,, 5. *T. punctata*, Sow. Test by reflected light. A thin outer flake is removed to show the round section of each punctation towards the inner surface of the test. × 14.

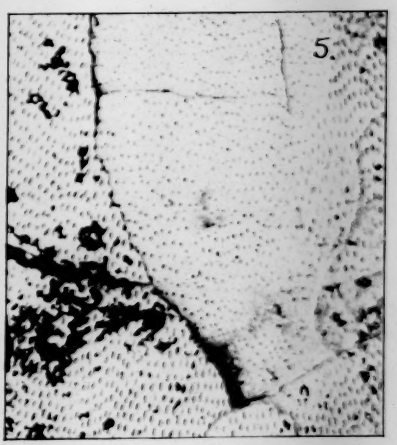
REFERENCES.

1. CARPENTER (Dr. W.). "On the Microscopic Structure of Shells": Rep. Brit. Assoc., 1844, pp. 16–18.
2. SHARPE (Daniel). "On *Trematis*": Q.J.G.S., vol. iv, p. 67, 1848.
3. SOLLAS (Professor W. J.). "Notes on the Cæcal Processes of the Shells of Brachiopoda interpreted as sense-organs": Sci. Proc. Roy. Dub. Soc., N.S., vol. v, 1886–7.
4. MORSE (E. S.). "On the Embryology of *Terebratulina*": Mem. Boston Nat. Hist. Soc., vol. ii, 1871–8.
5. KING (Professor W.). "On the Histology of the Test of the Class Palliobranchia": Trans. Roy. Irish Acad., vol. xxiv, p. 439, 1867.









TEREBRATULID SHELL-STRUCTURES.

III.—The Fluvio-glacial Gravels of the Thames Valley.

By R. M. Deeley, M. Inst. C.E., F.G.S.

(WITH A FOLDING MAP, PLATE IV.)

A CAREFUL examination of the distribution of the high-level gravels and sands of the Thames Valley, especially those associated with the boulder-clays, shows that in pre-Chalky Boulder-clay time, not only were the main valley lines marked out, but many even of the smaller valleys, such as the Brent, were in existence. Of course, during Pleistocene time, denudation has been very active; for over large portions of this area the boulder-clays, gravels, and sands now only occur as scattered patches.

Denudation has been most active in the valleys of the main watercourses, less so in the smaller watercourses, and least in the neighbourhood of ridges and high land. However, even in the main valleys, where the deposits were chiefly gravels and sands, the gravels and sands have protected the softer rocks below them, with the result that the gravels which once occupied the old valley bottoms now cap the hills and higher lands. In many situations the most elevated masses of boulder-clay rest directly upon the older rocks, whereas in lower positions the boulder-clays, especially the Chalky Boulder-clay, generally rest upon sands and gravels. We have here an indication that these sheets of gravel were laid down as extensive fluvio-glacial deposits, their heights above the sea depending upon the slope of the land and supply of material coming from the margin of the ice; or, in the case of valleys up which the ice was advancing and blocking the natural exits, upon the heights of the cols at their ends.

It must be remembered that both during the advance and the retreat of the ice-sheets vast volumes of water were thrown off at their fronts. When we consider that the ice which entered the Thames Valley came from the Scandinavian Peninsula, and that the greater portion of the precipitation on the ice-sheet which occurred between England and Scandinavia was liberated as water near the ice fronts, it is clear that an enormous volume of water was given off at the ice-sheet margins. Such melting took place both during advances and retreats of the ice. During the advances some of the precipitation was stored up as ice, and during the retreats some of the ice was melted, and increased the volume of water thrown off; but when we consider the slow nature of the advances and retreats, and the great length of time the ice-sheets persisted, it is clear that, as far as flood-water from the ice is concerned, periods of retreat did not differ greatly from periods of advance.

In the Thames Basin, with the exception perhaps of the estuarine portion, the whole district has been above the sea-level ever since the deposition of the Lenham Beds; consequently subaerial denudation had been active over the district for long ages before the Glacial Period, and there must have been an old river system in existence before the advent of the ice. However, as the directions of the main valleys in the unglaciated areas have always been largely as at present, in spite of the increasing development of subsequent streams,

the old river gravels have been largely destroyed as the rivers cut vertically and horizontally into the land.

For many reasons, in the process of excavating their valleys, rivers at various times bring their valley bottoms to base-level. They then cease to deepen them, but continue to attack the valley sides, and in course of time lay down extensive sheets of gravel. When a pause in vertical excavation persists for a long period, the surrounding high lands, when the rocks are soft, are denuded until we have a country of low relief through which the rivers course sluggishly over wide plains of gravel and of brickearth formed by floods.

The gravel deposits of the River Thames show that such pauses in vertical erosion occurred several times, for we have the remnants of several of these gravel plains at various heights, some of them forming terraces along the main river valleys, and others far removed from the present watercourses. However, whilst the rivers were excavating their valleys from one base-level to another, they also formed gravel deposits at intermediate heights. It thus comes about that there are *gravel patches at almost all heights above the rivers, but there are masses concentrated at particular levels.*

During the Pleistocene Period the ice-sheets reached the Thames Basin, and threw into the Thames Valley large quantities of gravel and sand. At these times gravel beds of exceptional thickness and of large area were formed. An endeavour will be made to connect these fluvio-glacial deposits with those of the fluvio-glacial fans near the old ice margins.

The suggestion that the pre-Chalky Boulder-clay Thames Valley, especially the eastern portion, was deeply excavated and subsequently partially filled up with fluvio-glacial gravel has already been made by T. I. Pocock.[1]

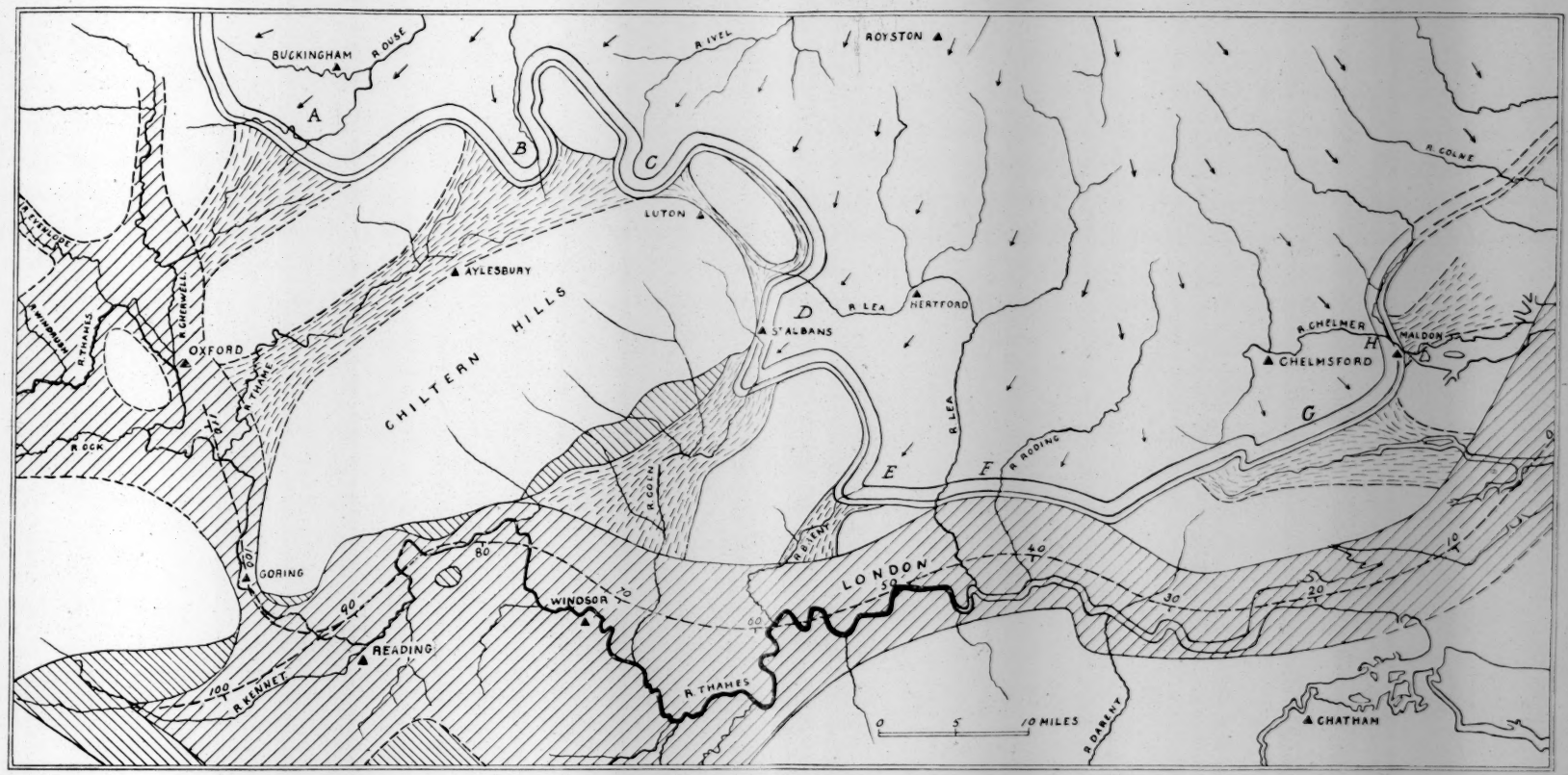
Bearing in mind the considerations outlined above, by the aid of the excellent Drift maps and memoirs published by the Geological Survey, it is possible to make a preliminary outline sketch of the conditions obtaining in the Thames Valley during the Chalky Boulder-clay stage.

To accomplish this object we must proceed from the known to the unknown. In the lower Thames Valley a good deal is known concerning the nature and distribution of the deposits left by the ice-sheet. The unknown is the actual physical condition of the valley in Glacial times; but here we can bring to our aid a knowledge of the nature of the deposits which are being formed by existing ice-sheets and glaciers in such regions as Alaska and Greenland.

The most profitable course to adopt in studying such an area as that of the Thames Valley is to obtain, if possible, a knowledge of the deposits formed at some particular stage, and use these as a datum with which to compare older or newer deposits.

When the ice which formed the Chalky Boulder-clay reached the north-eastern watershed of the Thames Valley it discharged into the Thames Basin great volumes of water and large quantities of gravel and sand. The deposits formed in this way contain numbers of rocks foreign to the Thames watershed. During such a time we had

[1] Geol. Surv. Summary of Progress, 1902, p. 201.



R. M. Deeley del.

Fig. 1

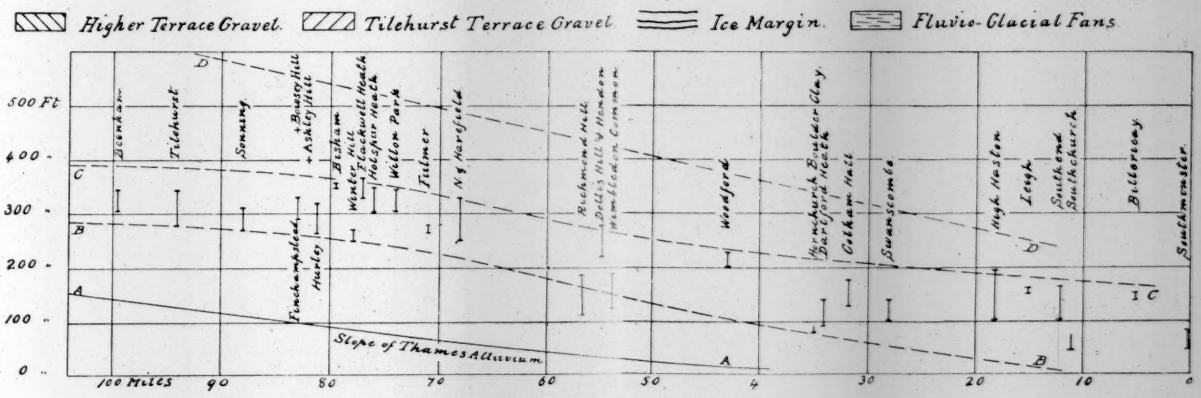


Fig. 2.

To illustrate Mr. R. M. DEELEY's Paper on "The Fluvio-Glacial Gravels of the Thames Valley."

a main valley in which the gravels were deposited over a wide belt, and other tributary watercourses flowing from the ice margin and forming fluvio-glacial fans of gravel and sand. A map showing the probable position of the ice margin, the fluvio-glacial gravel and sand beds in the tributary watercourses, and the area occupied by the fluvio-glacial deposits of the main stream, would furnish such a datum as we require.

If the conditions suggested above ever existed in the Thames Valley, then some of the gravel and sand deposits which exist on the hill-tops and valley sides of the Thames may have formed portions of the fluvio-glacial deposits.

The Map, Fig. 1, has been constructed to show what were probably the conditions obtaining when the ice which formed the Chalky Boulder-clay reached its maximum extension.

A considerable portion of the northern area of the map (Pl. IV, Fig. 1) is occupied by the ice-sheet of the Chalky Boulder-clay. From the various lobes, A to H, powerful streams of water escaped down the valleys of the Chelmer, Thame, Colne, Brent, Lea, Roding, and Crouch. These streams formed extensive fluvio-glacial fans, and threw large quantities of water-worn rock debris into the old Thames Valley. The probable area occupied by the gravels thus laid down is indicated by the coarse hatching. As the remnants of this deposit now occupy hill tops or shelves on the valley sides and are well developed on the hill on which Tilehurst stands, they have been called the Tilehurst Terrace Gravels. Some gravels, which are probably fluvio-glacial deposits of somewhat greater age, and lie at a higher level, are mapped as Higher Terrace Gravel. When the boundaries of the deposits are somewhat uncertain the lines have been dotted in. The dotted line, which runs along the Thames Valley from east to west, and is marked with a scale of miles, is the line of section along which Fig. 2 is drawn.

The ice margin has been drawn so as to include the most southerly patches of boulder-clay known. They probably do show the actual limits of the true glacier flow, but some of the lobes may have projected further down the valleys. West of Luton the ice rested near the edge of the Thames watershed. East of Luton the ice crossed the watershed and was arrested by high land in the Thames Basin. Indeed, the outliers of Chalky Boulder-clay show that the margin of the ice-sheet was determined largely by the topography.

Here and there lobes of ice pressed through the gaps in the hills. Working from west to east the main ice lobes are as follows:—

A. Buckingham Lobe. South of Buckingham there is a gap in the watershed between the Ouse and the Ray in which boulder-clays, gravels, and sands are largely developed. This seems to have been an important line of overflow; for from Stony Stratford past Buckingham to Charndon the overflow valley is well marked.

B. Leighton Buzzard Lobe. Here the ice stream curved round the hill to the south of Woburn and travelled as far at least as Leighton Buzzard.

C. Dunstable Lobe. At Dunstable there is a gap between the Chilterns and the high ground to the north-west, through which ice

passed. Whether the Leighton Buzzard and Dunstable lobes ever coalesced and passed down the valley towards Aylesbury is uncertain. If they did they may have sent floods down some of the gaps in the Chilterns as well as down the Thame Valley.

D. St. Albans Lobe. South of St. Albans there is a large patch of boulder-clay which shows that the ice passed through the gap between Hatfield and St. Albans. The gap has a height of about 250 feet. From the ice which passed through it a great amount of debris was thrown into the Thames Valley down the Colne River, in the valley of which there are wide spreads of gravel, some of the terraces of which are portions of the fluvio-glacial fan formed by the water liberated from the front of the Chalky Boulder-clay ice-sheet.

E. Brent Lobe. The gravels of Dollis Hill and Hendon show that an ice-flow from the north-east passed through a gap north of Hampstead and Highgate into the Brent Valley.

F. Lea Valley Lobe. The main ice invasion of the district covered by the Map, Fig. 1, came down the Lea and Roding Valleys and pushed its front into the then forming fluvio-glacial gravels of the Thames; for at Hornchurch the boulder-clay of this lobe has been found resting below the gravel. It must be remembered that the gravels we are considering and the Chalky Boulder-clay are contemporaneous deposits.

G. Crouch Valley Lobe. A considerable volume of ice mounted the watershed between the Chelmer and the Crouch. Some patches of sand and gravel in the Crouch Valley render it somewhat likely that this valley was occupied by a fluvio-glacial fan which ran in an easterly direction to the Thames Valley.

H. Malden Lobe. A lobe of ice passed towards the east, south of Tiptree Heath, and sent out a fluvio-glacial fan towards the north-east.

Other ice lobes moved towards the east down the valleys of the Suffolk rivers, but how far north the Thames then ran before reaching the sea is unknown at present.

The arrows over the northern portion of the map show the probable direction of the ice-flow. Harmer[1] has already given the probable directions of the flow of the ice from the north over the Fenland as far south as Royston. The directions of the ice-flow of the area we are dealing with, as shown on the Map, Fig. 1, are in entire agreement with his views concerning the movement of the more northerly portions of the ice. The coarsely hatched area, the greater portion of which follows the course of the Thames River, is the probable area occupied by the Tilehurst fluvio-glacial gravels of the main river when the ice reached its most southerly limits. Along the valley a dotted line has been drawn, and Fig. 2 is a section along this line. The present upper surface of the Thames alluvium is shown by the line A A. The slope amounts to about 2·5 feet per mile.

The terraces and patches of gravel we have to make use of to ascertain the levels and thicknesses of the fluvio-glacial gravels of the old Thames River are not very numerous, and are no doubt mere

[1] Jubilee Volume of the Geologists' Association, vol. i, p. 108.

fragments of the old deposit. Since these gravels were laid down the Thames has greatly deepened and widened its valley, and in doing so has destroyed the larger portion of the old deposits.

When first the water thrown off by the ice passed over the cols and entered the Thames Valley, it may have been muddy; but was free from gravel and sand, these latter being deposited in the valleys up which the ice was advancing, and were subsequently covered up by or converted into boulder-clay. The large volume of water thrown into the Thames Valley would first result in increased erosion and the destruction of much of the old Thames gravel of pre-Chalky Boulder-clay age. However, when the ice reached the watershed, then immense quantities of gravel and sand would be thrown into the valley, and the stream being unable to carry it away the gravel and sand would collect in the valley bottom and form a thick bed. When a river is thus aggrading its valley it does not form one wide stream, but breaks up into a form known as a "braided stream".

The Thames Valley may be divided into an upper or Oxford Basin above the Goring Gap, and a lower or London Basin below the Goring Gap, the Chiltern Hills and the high ridge to the south-west separating them.

When the ice margin stood on the north-east watershed of the upper basin, gravels were formed at heights of 100 feet or more above the present level of the Thames. However, in the Oxford Basin very cold climatic conditions existed even outside the Chalky Boulder-clay ice margin, and there is a marked absence of stratification in the Plateau Gravels of the region. Even if the ice did not override the watershed at one time, it is probable that heavy snow-drifts collected on the valley sides in sheltered positions, destroying older gravel terraces and disturbing gravels then forming.

In the Geological Survey Memoir for Oxford it is stated that the stones in the high-level gravels are a very mixed collection; among them occur numerous partially rounded flints a few inches across, liver-coloured quartzites doubtless from the Bunter Pebble Beds of the Midland Counties, white vein quartz, various coloured quartzites, hard sandstones resembling greywethers, soft sandstones with felspar of the Millstone Grit type, and black lydian-stone. The highest outlier on the Oxford sheet is at Bower's Hill, 540 feet O.D., but this deposit is doubtless much older than the Chalky Boulder-clay.

In the Oxford Basin the Plateau or Fluvio-glacial Gravels are not well developed, having suffered very considerably from the erosive action of the rivers and streams, and perhaps from the collection and movement of snow masses. However, there are some outliers of gravel, etc., at levels of 300 feet above O.D., which would appear to belong to the series formed when the Chalky Boulder-clay ice stood on the watershed to the north-east. The patches between Ipsden and Lewknor, extending along the edge of the Chilterns at heights of 300 to 400 feet above O.D., may be partly of this age; but as they are almost wholly flint gravels formed of materials derived from the weathering of the Chiltern Hills, they may be of various ages.

In the basin of the Thames at Chiselhampton and Great Milton, there are patches of gravel at heights of about 290 feet above O.D.

which may be connected with fluvio-glacial fans which came from the Leighton Buzzard and Dunstable Lobes, for they both contain pebbles of the Northern Drift. Patches of gravel at about the same height also occur in the neighbourhood of Oxford, etc. The drift deposits in the north-western portion of the Map, Fig. 1, have not been surveyed in detail, but enough is known to show that large fans of fluvio-glacial gravel from the Buckingham Lobe occur there. Owing to the fragmentary nature of the drift deposits in the Oxford Basin, and the fact that some areas have not been mapped in detail, the probable distribution of the fluvio-glacial deposits of this district have been drawn in dotted lines. The evidence furnished by these much disturbed and denuded high-level gravels is to the effect that when the Chalky Boulder-clay ice poured its debris into the Oxford Basin of the Thames Valley, portions of the basin had been denuded so as to form an extensive flat area which now stands about 300 feet above the sea. Over this area the fluvio-glacial gravels were spread in a great sheet covering such of the old river gravels as remained, and also the surrounding low country. The floor upon which the gravel rests is now wonderfully level, the slope towards the outlet of the Oxford Basin at Goring being quite small. The 300 feet fluvio-glacial gravels of the Oxford Basin may have been fifty feet thick, as they are further down the river; but mere fragments of them remain.

When a terrace is spoken of as being the 300 foot terrace it must be understood that the gravel and sand rest upon a platform of older rocks whose upper surface is at a height of 300 feet above O.D.

During the Chalky Boulder-clay period there must have been a very large stream of water flowing through the Goring Gap, a stream which partially dried up in the winter months. With this stream came Bunter pebbles into the London Basin, thus accounting for their presence to the west of points where they also reached the area from the St. Albans Ice Lobe.

On Fig. 2 the heights above the sea and thicknesses of a number of these outliers of gravel in the London Basin are plotted. The fluvio-glacial and other old gravels of this area, although the district has suffered much denudation, are less fragmentary in character than in the Oxford Basin. Indeed, they cover very considerable areas and their arrangement is much more easily traced.

In Fig. 2 the dotted line B B shows the average height of the bed upon which the 'schotter' formed by the 'braided streams' rested, whilst the line C C shows its upper limit. These levels must only be regarded as approximately correct. The gravel beds must have varied very considerably in thickness, often finishing off as a feather edge on the slopes of the valley sides. The gravel and sand patches which have been used to draw these lines are shown on the section, being named after some small town, village, or hill. The heights have been ascertained as closely as possible either from Ordnance Survey contoured maps or from the Drift coloured maps of the Geological Survey.

In the Thames Valley, east of Goring, and generally capping the higher Tertiary hills, there are deposits which Whitaker has called

the Pebble Gravel. The pebbles are well water-worn, and consist of flint, quartz, and quartzite. They are certainly much older than the Chalky Boulder-clay, as can be seen from the relationship of the two deposits near Potters Bar and the region immediately to the north-east. On Fig. 2 the dotted line D D shows the general slope of these Pebble Gravels to be about 4·4 feet per mile as we go east. However, the direction of the section is not quite along their dip slope. At one time the Pebble Gravels must have been a wide-spread deposit, but whether they are the remnants of the gravels of an old river and its tributary streams is uncertain. It is owing to the protection the gravels afforded to the soft rocks below that the deposit now occupies high ground above the softer surrounding rocks.

At much lower levels, and sloping in somewhat the same direction as the Pebble Gravel, we have what are here considered to be the fluvio-glacial gravels and sands of the Chalky Boulder-clay ice-sheet. They stand at heights which lie roughly, as previously stated, between the levels shown by the dotted lines B B and C C, Fig. 2.

In Fig. 1 the coarsely hatched area of the Tilehurst Gravels shows the ground which was probably occupied by the fluvio-glacial gravel of the Chalky Boulder-clay period. It is suggested that the bottom of the valley was then flat, denudation having reduced the level of much of the surrounding soft rocks to base-level, the whole area, where it was sufficiently low, being covered by a thick sheet of gravel. There may have been numerous ridges, low hills, and gravel terraces standing above the plain which were not covered by gravel, consequently the whole of the hatched area may not have been covered by the deposit.

In the neighbourhood of Goring the base of the gravel stands at about 300 feet O.D. Up the Kennet Valley it is a little higher, whilst it falls rapidly in an easterly direction. On this account it is not convenient to call the deposits the 300 foot terrace, and they will be referred to as the Tilehurst Terrace Gravels for distinctness.

At about ninety-four miles from the margin of the map, Fig. 1, there is a deposit of gravel and sand on the hill to the west of Tilehurst. Its highest point and the level of the rock terrace on which it rests are indicated by the vertical line. Monckton [1] describes this deposit, and some of the other gravels to be referred to, as glacial gravels, and states that they contain quartzites, large blocks of quartz, and igneous rock.[2] By the Geological Survey they are described as being as a whole "distinctly current-bedded, though this character is more conspicuous in some pits than in others".

In the Kennet Valley on the ridge to the north-east of Beenham, at nearly 100 miles, there is gravel and sand at about the same level as at Tilehurst. Other high-level gravels at Sonning, Finchampstead, Hurley, Bisham, and Winter Hill belong to this terrace.

From Flackwell Heath to Harefield the deposits plotted are those of the St. Albans Ice Lobe, glacio-fluvial fan gravels and sands. In

[1] Q.J.G.S., vol. xlix, p. 309, 1893.

[2] *The Geology of the Country around Windsor and Chertsey* (Mem. Geol. Surv.), p. 60.

the Colne Valley, 3 miles south of St. Albans, is a patch of Chalky Boulder-clay resting upon sand and gravel. The gravel comes down to a level of about 230 feet, and the Boulder-clay lies between the levels 250 and 290 feet or thereabouts, whilst the same deposit of gravel is from 310 to 335 feet high on the other side of the river to the south-east. The presence of a patch of Boulder-clay up the Colne River, 12 or 14 miles from the Tilehurst Terrace Gravels, and almost as low down as the section line B B, Fig. 2, is remarkable. However, the fluvio-glacial gravels near the Boulder-clay patch rise as high in places as the section line C C where it passes the confluence of the Colne River and the Thames.

It would appear that the Chalky Boulder-clay ice built up in front of it a mass of gravel and sand whose upper surface was considerably above the lower level of the ice and boulder-clay. When this takes place and the glacier is retreating, large masses of glacier ice are left beneath the gravel plain, and these melting out form great pits in the alluvial deposits. Such a condition of affairs may now be seen in the valley of Hidden Glacier,[1] Alaska.

(*To be concluded in our next number.*)

IV.—The Divisions of the Eocene of Egypt as determined by the Succession of the Echinid Faunas.

By René Fourtau, Member of the Egyptian Institute, etc.

A VERY remarkable fact in the palæontological study of the Eocene strata of Egypt is the succession of echinid faunas, which seem definitely localized at well-determined horizons, enabling these to be recognized with ease.

The opening of the Eocene period is marked by the appearance of a group consisting of *Conoclypeus Delanouei*, de Loriol, *Plesiospatangus Cotteaui*, de Loriol, *Linthia cavernosa*, de Loriol. *C. Delanouei* characterizes the strata to which the Egyptian geologists have given the name of *Libyan*. *L. cavernosa* appears almost at the same time as *C. Delanouei*, but disappears earlier; it is no longer met with in the upper beds of the Libyan stage, which are characterized by the abundance of Foraminifera of the genus *Alveolina*, and in which a new echinid fauna is recognized. Finally, *Plesiospatangus Cotteaui* occurs only in the central portion of the Libyan stage.

In addition to these three very abundant species, others of less frequent occurrence may be mentioned. Such are *Opisaster thebensis*, de Loriol, exclusively restricted to the lower part of the Libyan stage; the group of *Megapneustes* (*M. Sickenbergeri*, Mayer-Eymar, *M. Lorioli*, Gauthier, *M. grandis*, Gauthier), and *Linthia Delanouei*, de Loriol, which are only met with in the central portion.

The upper part of the stage, which has received the special name of the "Alveolina Series", contains, in addition to *C. Delanouei*, *Echinopsis libyca*, de Loriol, *Echinolampas Humei*, R. Fourtau, *Sismondia Logotheti*, Fraas, *Hypsospatangus Lefebvrei*, de Loriol.

C. Delanouei is represented at this horizon by a somewhat peculiar

[1] *The Yakutat Bay Region, Alaska*, by R. S. Tarr, p. 63.

variety in which the periproct is unusually developed, tending to be nearly as broad as it is long, and penetrating the posterior border; *E. Humei*, very rare below, abounds in certain localities; *S. Logotheti* is restricted to the "Alveolina Series", but only in the south; to the north it is replaced by *S. varians*, R. Fourtau, which is also limited to this horizon. *E. libyca* and *H. Lefebvrei* are among the most characteristic forms and are present almost everywhere.

In addition, the "Alveolina Series" yields a number of forms which are only prevented by their very narrow localization from being characteristic: such are *Leiocidaris miniehensis*, Mayer-Eymar; the genus *Gisopygus* (two forms of which appear at a slightly lower horizon), which attains a splendid development in the "Alveolina Series", to disappear almost completely with them; *Kephrenia Lorioli*, R. Fourtau, *Schizaster miniehensis*, R. Fourtau, *Euspatangus Lamberti*, R. Fourtau, and *Cheopsia Mortenseni*, R. Fourtau.

Thick masses of limestones containing enormous numbers of *Nummulites gizehensis*, Ehr., appear above the "Alveolina Series" in Egypt. With them, the echinid fauna changes absolutely. The species we have just mentioned disappear, making way for others which have not yet been found in the lower strata. These are: *Porocidaris Schmidelii*, Münster, *Echinolampas africanus* and its variety *Fraasi*, de Loriol, *Schizaster africanus*, de Loriol, *S. moqattamensis*, de Loriol, *Euspatangus formosus*, de Loriol. These forms are met with throughout the mass of limestones with *Nummulites gizehensis*, accompanied according to locality by less abundant species such as: *Leiocidaris Abbatei*, Gauthier, generally distributed, *Brissospatangus Humei*, R. Fourtau, in the southern area, *Orthechinus moqattamensis*, Cotteau, and *Brissopsis Lamberti*, Gauthier, in the northern portion. Then follow a whole series of limestones in which no echinids have been found. They are characterized by the abundance of branching Bryozoa and Serpulæ.

The strata above these limestones are almost lacking in Nummulites, but yield a special sea-urchin fauna, including: *Rhabdocidaris Gaillardoti*, Gauthier, *Thagastea Luciani*, de Loriol, *Echinolampas Crameri*, de Loriol, *Anisaster gibberulus*, Michelin. To these may be added the following species, which are more rarely met with: *Thylechinus libycus*, R. Fourtau, *Echinolampas moelehensis*, R. Fourtau, in the southern area, *Sismondia Blanckenhorni*, Gauthier, and *Clypeaster Fourtaui*, Lambert (= *C. Breunigi*, de Loriol, *non* Laube), in the northern portion.

Above these deposits is a series of marly or calcareous strata without sea-urchins, and in the Fayum mainly containing vertebrate remains.

These successive faunas enable us to establish definite divisions for the Eocene of Egypt.

In the first place, we can define two main divisions of which the line of demarcation is easily traced in consequence of the disappearance of *Conoclypeus Delanouei* and the appearance of *Echinolampas africanus*, which inaugurates the group of conoclypeiform *Echinolampas*, apparently derived from *C. Delanouei*.

This demarcation line also corresponds with a notable change of facies and with the appearance in Egypt of the large Nummulites constituting the *N. gizehensis* group. These two divisions have been long established and adopted almost unanimously by geologists who have studied the Eocene of Egypt. They are the Libyan and Moqattamian Stages.

The Libyan Stage can be subdivided into—

1. Lower Libyan, where *C. Delanouei* is present alone with *Linthia cavernosa*.

2. Middle Libyan, in which with *C. Delanouei* and *L. cavernosa* appear *Plesiospatangus Cotteaui* and the group of *Megapneustes*, which is only found at this horizon.

3. Upper Libyan, long ago separated under the name of "Alveolina Series", which still contains some *C. Delanouei*, but none of the other species. These are replaced by small forms, of which the most abundant is *Hypsospatangus Lefèbvrei*.

The Moqattam Stage, which following the rules of nomenclature we should term Moqattamian, can be easily divided into two sub-stages—

4. The Lower Moqattamian is characterized by large conoclypeiform *Echinolampas*, together with *Schizaster africanus* and *Euspatangus formosus*.

5. The Upper Moqattamian in which the sea-urchin species of large size are replaced by others that are quite small, such as *Thagastea Luciani*, *Echinolampas Crameri*, *Anisaster gibberulus*, accompanied by *Schizaster vicinalis*, Agassiz, while in the uppermost layers the genus *Clypeaster* appears for the first time in Egypt.

The synchronization of the local divisions is somewhat delicate, and has of late given rise to somewhat lively discussion. The Echinids have not been used to establish the divisions adopted in Europe, and latterly efforts have been mainly applied to determining a Nummulite scale, which, it must be admitted, has given good results in many places, but which might give rise to criticism when applied to other localities and especially North Africa. It is not easily to be explained, for instance, why, in Tunis and Algeria, the beds with *Nummulites gizehensis* are attributed by everybody to the Lower Eocene, whereas in Egypt all agree as placing them in the Middle Eocene. The study of the *Cerithium* group has given fairly good results in the Paris Basin, but division on such a basis is impossible in Egypt, where these Gasteropods are rare, and when present are usually distinct species.

It might be therefore useful to take the succession of echinid faunas and changes of facies as our basis in attempting to subdivide the Eocene of Egypt, and to attach only a relative value to synchronizations founded on widely separated faunas. The Table (p. 67) indicates the solution which appears to me the most satisfactory.

The synchronizations which I propose in this Table appear to me rational. There might, however, be discussion as to the desirability

Egyptian Stages.			Echinid Fauna.	Facies.	Equivalent in the General Series.	
Lower Eocene or Libyan.		Lower Libyan.	*Conoclypeus Delanouei, Linthia cavernosa, Opisaster thebensis, Palæostoma Zitteli.*	Siliceous limestones, not very fossiliferous.	Thanetian.	
		Middle Libyan.	*C. Delanouei, L. cavernosa, Plesiospatangus Cotteaui, Linthia Delanouei,* the genus *Megapneustes, Cassidulus Romani, Euspatangus Peroni, Hemiaster Schweinfurthi.*	White siliceous limestones with some marly beds. Limestones with flint concretions. Very marly limestones.	Suessonian.	Londinian.
		Upper Libyan.	*C. Delanouei,* var. *macropyga, Hypsospatangus Lefebvrei, Sismondia Logotheti, S. varians, Echinolampas Humei, Leiocidaris miniehensis,* the genus *Gisopygus, Kephrenia Lorioli, Schizaster miniehensis, Euspatangus Lamberti, Cheopsia Mortenseni.*	White limestones with some beds of flint, crowded with *Alveolina.*	Ypresian or Cuisian.	
Middle Eocene.	Moqattamian.	Lower Moqattamian.	*Leiocidaris Abbatei, Porocidaris Schmidelii, Orthechinus moqattamensis, Echinolampas africanus* and var. *Fraasi, Brissospatangus Humei, Brissopsis Lamberti, Schizaster africanus, S. moqattamensis, Euspatangus formosus.*	Nummulitic limestones, more or less glauconitic.	Lutetian.	
			—	White limestones with Bryozoa and Serpulæ. Marly limestones.	Auversian.	
Upper Eocene.		Upper Moqattamian.	*Rhabdocidaris Gaillardoti, Thylechinus libycus, Thagastea Luciani, Sismondia Blanckenhorni, Clypeaster Fourtaui, Echinolampas Crameri, E. moelehensis, Anisaster gibberulus.*	Brown marly or siliceous limestones, separated by thick beds of salty and gypseous marls.	Bartonian.	
			—	Marls with some calcareous beds. Marly sands with vertebrate remains.	Ludian and Tongrian.	

of including the Bartonian and the Ludian in the Middle Eocene, and of only beginning the Upper Eocene with the Tongrian. The stratigraphical divisions adopted in Europe correspond to marked oscillations of shore-lines, and their delimitation is easy. It is not so in the Mediterranean Basin and especially in its southern part, which, during the whole of the Eocene period, was a region of continuous sedimentation. I have thought that the sea-urchin faunas could help us to establish subdivisions, and have given the result of my researches without stopping at simple questions as to where the brackets representing individual divisions should be drawn.

I am greatly indebted to Dr. W. F. Hume, F.G.S., etc., Director of the Geological Survey of Egypt, for kindly translating this paper into English.

V.—On two Borings for Water at Hinckley, Leicestershire.

By A. J. Pickering.

THOUGH Hinckley is now possessed of an excellent supply of water brought from the Lower Keuper Sandstone of Snarestone, in North-West Leicestershire, up to 1891 it had an unenviable reputation for abortive water-schemes. Some £20,000 had been spent in considering eighteen different propositions and in carrying out three deep borings within a few miles of the town. During this time six consulting engineers were called in by the local authority. All these schemes failed, not through any lack of water—for this was obtained from the Waterstones of the Lower Keuper in almost unlimited quantity—but because it was found impossible to shut out the chlorides and sulphates from the gypsiferous Keuper Marls through which the borings passed.

Recently two attempts have been made by private firms in the town to obtain a supply of water from the Upper Keuper Sandstone, but unfortunately these schemes have been abandoned without satisfactory results.

The first was carried out for Messrs. Atkins Bros. at the rear of their factory in Bond Street in the centre of the town. Boring was commenced in July, 1913, from the bottom of an existing well 41 feet deep. This had up to late years yielded an excellent supply from the Drift deposits (here about 135 feet in thickness), but had gradually been drained, probably by the sinking of deep foundations in the lower levels of the town and by extensive building operations in the higher levels. This latter would have the effect of diminishing the quantity of rain-water making its way into the water-bearing drifts. In this boring the jumping-chisel method was employed throughout; consequently the thicknesses of the beds were somewhat difficult to ascertain. In the following table they must be taken as only approximate. Operations were abandoned in 1914 after repeated attempts to recover a boring-tool, and through the falling-in of the unlined portion of the borehole.

The following is the section :—

WELL AND BORING, BOND STREET, HINCKLEY.

(125 yards south-east of junction of Bond Street with Upper Bond Street and the Hollycroft.) [1]

	Thickness. Feet.	Depth. Feet.
1. Top soil	2	2
2. Chalky boulder-clay	10	12
3. Sand and loamy sand	29	41
4. Sand and running sand, light brownish-yellow	11	52
5. Red-brown clay, sandy	3	55
6. Grey-brown sand	5	60
7. Brown silty clay	10	70
8. Loams and clays, very fine, light-brown	10	80
9. Brown silty clay (as No. 7)	9	89
10. Reddish-brown silty clay	11	100
11. Dark-brown clay	10	110
12. Light-brown clay	18	128
13. Dark-brown clay with pebbles of ironstone and grit and patches of red marl	7	135
14. Light-red marl with green spots and small pebbles	25	160
15. Light-green and red marls with thin bands of sandstone	30	190
16. Red marls with green mottling	8	198
17. Coarse grit	3	201
18. Marls with gypsum	22	223
19. Hard grey sandstone, fine-grained	2	225
20. Hard red marl	19	244
21. Sandstone (as No. 19)	5	249
22. Hard sandstone, close-grained	7	256
23. Red marl without gypsum	34	290
24. Red marl with green spots and traces of gypsum	10	300
25. Hard red marl	8	308
26. Harder red marl with conchoidal fracture	Undetermined.	

No. 2 is the typical Chalky Boulder-clay of the Midlands, containing here a considerable number of Chalk flints and Jurassic fossils; of these the *Gryphæa arcuata* is the most common. It is blue-grey in the higher beds, but assumes a redder colour as it approaches the underlying sands. In and near Hinckley it often becomes gravelly, the clay being replaced by a coarse sandy matrix. This gravel is sometimes matted together by a calcareous cement.

Nos. 3, 4, 5, and 6 are a sandy series of the Drift, and are, or have been, exposed in many sandpits in and around the town. They vary considerably in appearance, some beds being red and loamy, others pale-yellow and of a 'sharp' and crystalline nature; in the latter case the sands weather quickly to a loam on exposure. Interstratified with this sandy series are a few bands of very fine gravel, containing derived shell-fragments in beds of not more than an inch or two in thickness. They also contain thin streaks of black carbonaceous material, probably coal-dust. Current-bedding is conspicuous in all the sands, which are entirely devoid of flints, and are mainly derived

[1] Six-inch map, Leicestershire 42 N.E.; one-inch New Series map 169 (Nuneaton); one-inch Old Series geological map 63 S.W. Height above O.D. about 410 feet. Rest-level of water about 80 feet from surface. Pumping-test at a depth of 305 feet yielded 1,400 gallons per hour. Old sunk well 41 feet, new borehole 267 feet; total depth 308 feet. Made by Messrs. Peacock & Bird, Hinckley. Commenced July 23, 1913; abandoned January, 1914. Chisel used throughout.

from Triassic outcrops. From their position they may be, I think, correlated with the Quartzose Sand of the Lower Pleistocene identified by R. M. Deeley in the Trent Valley. Wherever these sands occur in the neighbourhood of Hinckley they are underlain by thick beds of clay; consequently they form a natural reservoir and yield a considerable supply of water whenever penetrated below the valley levels. During a recent enlargement of the main sewers in the lowest part of the town these beds of sand were encountered, and the contractors experienced great and unforeseen difficulties in keeping the running sand from their trenches. A large portion of the street subsided as a consequence of the washing away of the underlying sand.

Beds 7 to 12 are a series of clays or brick-earths, which are, or have been, worked in several brickyards north, east, and west of the town, e.g. at Messrs. Hudson's works, Barwell Lane. They are quite free from erratics, save a few small pebbles of quartzite and felsite.

Nos. 13 and 14 are the lowest beds of the Drift. They contain a considerable proportion of Keuper Marl material, also numerous Bunter pebbles and rolled fragments of Coal-measure sandstone.

Nos. 15 and 16 appear to be Upper Keuper Marls with bands of coarse sandstone or skerry.

Nos. 17 to 22 contain a succession of fairly massive beds of Upper Keuper Sandstone of varying degrees of hardness, with an intervening 22 ft. bed of mottled marl with a little gypsum.

Nos. 23 to 26 belong to the thick lower series of Keuper Marls containing the usual bands of gypsum.

The second boring was begun for Messrs. A. E. Hawley & Co., at their Sketchley Dye Works, early in 1915. After boring 213 feet without any satisfactory results the work was abandoned (for the present) in August last. Unfortunately the first 110 feet were bored by the percussion process, so that again it was impossible to ascertain the thickness of the Glacial Drift with any degree of accuracy. From 110 to 213 feet the engineers used the shot-drill, extracting cores of about 7 inches in diameter.

The following is the section :—

WELL-BORING, SKETCHLEY DYE WORKS, HINCKLEY.[1]
(330 yards S. 7° W. of railway-bridge over Rugby Road.)

	Thickness.		Depth.	
	ft.	in.	ft.	in.
1. Top soil, sand and gravel	2	0	2	0
2. Red clay	8	0	10	0
3. Brown silty clay	40	0	50	0
4. Brown silty clay intermixed with red marly clay 5. Brown silty clay with fragments of red marl, small pebbles of quartzite, and pieces of green sandstone 6. Red marl with quartzite pebbles (pebbles larger towards base)	25	0	75	0

[1] Six-inch map, Leicestershire 42 N.E.; one-inch New Series map 169 (Nuneaton); one-inch Old Series geological map 63 S.W. Height above O.D. about 327 feet. Engineer, Mr. Chas. J. Ell, Luton, Beds. Commenced February, 1915; work suspended following August.

	Thickness.		Depth.	
	ft.	in.	ft.	in.
7. Clear red marl 8. Red and green marls 9. Red marls with small quantity of gypsum	21	0	96	0
10. Hard red marl 11. Red marl with a little green marl	14	0	110	0
12. Hard red marl	3	0	113	0
13. Green marl	0	6	113	6
14. Red marl	6	6	120	0
15. Red marl with three 2 in. bands of gypsum	2	0	122	0
16. Red marl	7	0	129	0
17. Mottled (red and green) marl with little gypsum	2	0	131	0
18. Green marl	0	7	131	7
19. Red marl	2	0	133	7
20. Gypsum	0	1	133	8
21. Red marl	6	0	139	8
22. Green marl	1	6	141	2
23. Red marl	1	6	142	8
24. Gypsum	0	3	142	11
25. Red marl	1	1	144	0
26. Mottled marl with gypsum veins	3	3	147	3
27. Red marl, calcareous	0	8	147	11
28. Mottled marl with gypsum veins	1	6	149	5
29. Green marl	0	4	149	9
30. Mottled marl, chiefly red	2	3	152	0
31. Gypsum	0	2	152	2
32. Mottled marl, chiefly red	4	0	156	2
33. Green and red marl with gypsum; contorted bedding-lines	1	6	157	8
34. Gypsum	0	2	157	10
35. Green and red marl; horizontal bedding	4	9	162	7
36. Red marl with three bands of gypsum	3	0	165	7
37. Red marl	5	0	170	7
38. Red marl with veins of gypsum	1	10	172	5
39. Green marl	0	10	173	3
40. Gypsum	0	1	173	4
41. Red marl	2	9	176	1
42. Red marl with thin veins of gypsum	4	0	180	1
43. Red and green marl	0	6	180	7
44. Gypsum	0	2	180	9
45. Red marl	2	6	183	3
46. Gypsum	0	1	183	4
47. Red marl, slightly mottled	2	8	186	0
48. Gypsum	0	3	186	3
49. Red marl	2	8	188	11
50. Gypsum	0	1	189	0
51. Red marl, slightly mottled	1	3	190	3
52. Red marl with veins of gypsum	2	0	192	3
53. Red marl	1	9	194	0
54. Gypsum	0	1½	194	1½
55. Red marl	4	0	198	1½
56. Green marl	0	6½	198	8
57. Red marl with a little gypsum	2	6	201	2
58. Green marl	0	7	201	9
59. Red marl with veins of gypsum	2	5	204	2
60. Red marl	3	0	207	2
61. Gypsum	0	1	207	3
62. Red marl	4	0	211	3
63. Gypsum	0	1	211	4
64. Green marl	0	4	211	8
65. Red marl	1	6	213	2

It will be noticed that this boring commenced at the bottom of the sandy Drift series. The site being 83 feet below Messrs. Atkins's boring, the Chalky Boulder-clay was not present.

Beds 2 and 3 are the silty clays, and Beds 4, 5, and 6 are the Keuper Drift beds before mentioned. Below these the compact red marls of the Keuper were penetrated, and these continued with interbedded green marls and gypsum as far as the boring was carried.

With the exception of indications of contemporaneous puckering in Bed 33 the whole of the cores were horizontally bedded.

The absence of all trace of the Upper Keuper Sandstone (either in the sediment of the earlier portion of the boring, or in the cores) is a little remarkable, inasmuch as the site is little more than three-quarters of a mile from the boring at Messrs. Atkins Bros., where beds up to 7 feet in thickness were penetrated. The Holy Well boring,[1] begun in 1875 a little farther east, also gave about 30 feet of Upper Keuper Sandstones; but at the Wharf boring,[2] 1¼ miles west of the Holy Well and half a mile west of the Sketchley Dye Works, only 12 feet were present.

This absence of the Upper Keuper Sandstone in the Sketchley borehole may be due to one of several causes. Firstly, this sandstone is known to be impersistent at its outcrop in many parts of the Midlands, and is liable in places to thin out, and elsewhere to be split up by beds of marl. There is evidence, too, that more than one band comes in at about this position in the Keuper Marl. Sometimes several bands may be present together in one district, while a little farther on one or other of these bands may thin out. Secondly, although present at the Holy Well and at Bond Street, it may have cropped out against the base of the Glacial deposits before reaching Sketchley. Thirdly, there may be a gentle syncline under Sketchley, by which the sandstone is carried down below the bottom of that boring. This third explanation is supported by the fact that between the Holy Well and Bond Street the base of the sandstone falls 88 feet. If this fall is maintained it would carry the bed below the bottom of the Sketchley boring.

It is to be noted that at the Holy Well the distance between the top of the Waterstones (=Lower Keuper Sandstone) and the bottom of the Upper Keuper Sandstone is 217 feet, whereas at the Wharf the distance is 396 feet. It is probable, therefore, that the Upper Keuper Sandstone of the Holy Well thins out or splits up before reaching the Wharf, and that the Upper Keuper Sandstone at the Wharf, 12 feet thick, is a higher band.

An examination of the cores showed both the red and the green marls to be entirely devoid of organic remains. The green marls were throughout much harder and coarser-grained than the red, and portions were slightly calcareous. The red marls quickly decomposed on exposure; but the green marls showed little signs of weathering. The usual bands of skerry were entirely absent.

The writer is indebted to Messrs. Atkins Bros. and to Messrs. A. E. Hawley & Co. for permission to watch the boring operations, to

[1] Rep. Brit. Assoc. for 1875, p. 136; for 1879, p. 160.
[2] Ibid. for 1882, p. 226; for 1883, p. 154; for 1887, p. 364.

measure and describe the materials brought up, and to put the results on record. This work has been facilitated in every way by the boring firms engaged.

For several suggestions and general encouragement the writer is indebted to Mr. T. C. Cantrill, of the Geological Survey.

VI.—Calcium Carbonate and Evolution in Polyzoa.[1]

By W. D. Lang, M.A., F.G.S.

In a review in the Geological Magazine for 1913[2] of an important paper by Cumings on the development and systematic position of the Monticuliporoids, it was pointed out that the elucidation of the post-embryonic stages of that group conclusively proved them to be Polyzoa, and disposed of Kirkpatrick's contention that they were allied to *Merlia*, a recent siliceous sponge. Thus, further to prove the dissimilarity between the Monticuliporoids and *Merlia* is to flog a dead horse. Nevertheless we welcome the excellent figures by Cumings and Galloway of the microscopic structure of the two organisms showing that the skeleton of the one is formed of superposed layers and the other of radiate spicules so adjusted as to form a mesh-work.

The authors, however, are not mainly concerned with the connection of *Merlia* and the Monticuliporoids, but with the Trepostome wall and various correlated structures, namely Cysts and Cystiphragms, Intrazoœcial spines, Acanthopores and Communication-pores. They point out that Communication-pores of Palæozoic Trepostomata resemble those of *Heteropora*—a form that persists until recent times; that Acanthopores are the continuations below the general zoarial surface of hollow spines, "undoubtedly protective" in function, which, in unworn specimens, project above the surface; that "certain extraordinary spines projecting into the submature region of zoœcia of a species of *Nicholsonella*" resemble those of *Heteropora neozelanica*, as figured by Nicholson. They make the very interesting and ingenious suggestion that Cysts and Cystiphragms are the expression of the renewal of the polypide on the formation of a Brown Body (a familiar process among recent Polyzoa) and that the purpose of the ectocyst in laying down a fresh wall at each such crisis is the "restriction of intrazoœcial space"; moreover, the occurrence of minute concretions of some iron compound in the Cyst, i.e. the space enclosed by the cystiphragms, is claimed to be produced by the decay of the degenerated polypide.

Finally, the structure of the wall is considered. Hitherto it has been customary to divide the Trepostomata by their walls into two groups—Integrata, those that have a dark median line in the wall in virtue of which each half is claimed for that zoœcium adjoining it—and Amalgamata, in which there is no dark line, but the walls of two

[1] [Originally written as a review on "Studies of the Morphology and Histology of the Trepostomata or Monticuliporoids", by E. R. Cumings and J. J. Galloway, 1915, Bull. Geol. Soc. America, Vol. xxvi, pp. 349–374, Pls. 10–15, but considered more appropriate as an original paper.—Ed.]

[2] Geol. Mag., Dec. V, Vol. X, pp. 32–36.

adjacent zoœcia are completely confluent. Cumings and Galloway show that this distinction does not hold—that Lee had already remarked that the presence or absence of the dark line was inconstant—and their researches correlate the presence of the dark line with the thinness of the growing edge of the wall and the consequent "steep pitch" of the growth-laminæ. "For some reason, wherever the wall laminæ of the trepostomes are sharply bent the material appears dark . . . It is probable that the size and arrangement of the minute granules of which the wall laminæ are composed differ slightly at such points from the normal size and arrangement in other parts of the wall. In fact, in well-preserved material and in very thin sections it can be shown that this is actually the case."

The similarity of the Trepostome wall with that of the Brachiopoda when they are viewed in thin sections is pointed out, and "in such sections as are shown in figures 45 and 49 it amounts almost to identity".

Perhaps the most interesting part of the paper concerns the Cingulum or secondary thickening of the wall, and its relation to the secretion of diaphragms and cystiphragms which are clearly shown in the figures to be continuations of this secondary thickening. The authors regard the thickening as an old-age character. "The thickening of the interzoœcial walls, due to the development of the cingulum, is often very great—far greater than would merely compensate for the increasing separation of the zoœcia, as they extend radially outward from the axial region. There is an actual reduction in size of the zoœcial chamber; indeed, in some cases, an extreme reduction (figures 1 and 17). We believe that this extreme development of secondary deposits is a senile feature, analogous to the great thickening of brachiopod shells and the shells of the Mollusca in old age. In recent Bryozoa the zoœcia of the older portions of zoaria often become almost or quite filled up with stony deposits, and it seems that the ectosarc [ectocyst] may continue to secrete such deposits after the polypide has wholly disappeared from the zoœcium."

Let us go further. Say that some metabolic process, such as one involved in nitrogenous excretion, resulted in the precipitation of calcium carbonate in the tissues or upon the surface of a marine organism—Mollusc, Brachiopod, or Polyzoan, and was turned to useful account as affording a supporting or protecting skeleton or shell; that this production of calcium carbonate became increasingly constitutional so that the mere need for a skeleton or shell was more than met; that the process could not be arrested or countered in all the organisms that had acquired it, and in these the disposal of superfluous calcium carbonate became a pressing problem; that, finally, those organisms that found no way out of the difficulty were doomed to extinction under a mass of calcium carbonate of their own making.

At some time or other most animal phyla have met the calcium carbonate problem in an acute form. The Protozoa can always crawl away from their skeleton, and many organisms that build tubular shells can similarly move up their tubes which thus become of indefinite length, while tabulæ, diaphragms, etc., are merely the

superfluous calcium carbonate of the organism's after end in its new position. Even Gasteropod Molluscs to a certain extent can behave in this manner. The Arthropods wrestle chiefly with chitin and throw off its accumulation at each ecdysis; but such marine forms as add calcium salts to chitin tend to be cumbered more and more with their exoskeleton at the periodic moults in proportion to the amount of calcium present. Some Molluscs, like the *Rudistæ*, have succumbed to masses of calcium carbonate, but the most successful, apparently, have learnt how to circumvent its secretion and produce little or no shell. The point need not be laboured, but this aspect of the deposition of calcareous skeletal matter may help to explain much that is not otherwise clear in the structure and evolution of Polyzoa.

The simplest Polyzoa—the less differentiated Cyclostomes—have tubular skeletons, and merely add to the length of their tube, occasionally inserting a diaphragm, and an entombing cap or 'closure' may be the moribund act of a senile individual. As the colonies become more massive it is required that the general zoarial surface should remain at the same level, and this could not be attained if each individual independently moved up its tube according to its capacity for calcium carbonate secretion. The forward movement would, therefore, be general and slow, and the deposit of calcium carbonate would be chiefly directed to the interzoœcial spaces which generally would tend to widen as the tubular skeletons radiated from a common centre. This is the condition of the more complicated Cyclostomes and the Trepostomes and Cryptostomes in general. But, though the uneven projection of individuals from the surface of the colony is undesirable, skeletal projections that did not interfere with the currents and food supply would not only be harmless, but might even serve a protective purpose. Thus, when the pressure again became intolerable, acanthopores might arise. Again, if the insistence of calcium carbonate was severe, the whole of the ectocyst capable of, yet not actually, secreting would be in a state of unstable equilibrium, an external stimulus might start the deposition of calcium carbonate at any point, and an intrazoœcial spine result. Cumings and Davenport do not suggest a utilitarian origin for these. "What possible functions these spines could have we do not venture to say." The renewal of the polypide may well have given the necessary stimulus for the formation of cystiphragms and been the excuse for depositing calcium carbonate even if there were no other need for it. Finally, it is unnecessary to look for any special utility in the massive secondary wall-thickening termed by the authors the cingulum, if the whole organism is (so to speak) aching to deposit it. Cumings and Davenport attribute the secondary thickness of the walls to senility of the individual, at least they say it accompanies senility. We claim, further, that it marks the senility of the lineage to which the individual belongs, and it is by turning to harmless or possibly useful account the same ever-present danger that other structures described in this paper are due.

Such a conclusion has been impressed upon the writer by the study of Cretaceous Cheilostomes. The Cyclostomes and Trepostomes have been considered. The Cryptostomes divert their excess of calcium

carbonate into the elaboration of secondary apertures. The Cheilostomes do the same with marked (temporary) success. But this is only one of their methods. The most hopeful of the Cheilostomes are those which have a skeleton of chitin only. When once calcium carbonate has begun to be deposited the whole lineage is doomed to a more or less stereotyped sequence of calcification until, in the end, it becomes extinguished under its superfluity of skeleton. For obvious reasons it is only these doomed lineages that we have to deal with as fossils; and the evolution of the Cretaceous Cheilostomes, as far as we can have any knowledge of it, is the story of the progressive elaboration of the calcareous skeleton until this becomes secondarily simple by the blotting out of its complexity under secondary deposits.

The simplest Cretaceous Cheilostomes—'Membranimorphs'—have calcareous skeletons with no intraterminal front walls.[1] Senility in an individual results in the complete calcification of the intraterminal front wall and the consequent death of the zooid, since even the orifice is sealed up. Before this takes place, however, superfluous calcium carbonate, in some forms, is deposited as terminal spines.[1] The general phylogenetic future of some of these, namely those in which the terminal spines, arching over, fuse with their opposing and lateral neighbours—'Cribrimorphs'—can be predicted with certainty, though the details vary in every lineage. Further calcium carbonate is laid down in connection with (1) the spines that form the intraterminal front wall—the costæ; (2) those that surround the aperture—the 'apertural spines' (considered with the first pair of costæ, those which bound the aperture proximally, and, fused, form the 'apertural bar'); and (3) the extraterminal front wall, finally filling up the interzoœcial angles; and the process may take place in one or more of these directions simultaneously in any lineage. The first method results (with various modifications in various lineages) in a solid, arched, intraterminal front wall; the second (with various interfusions of the apertural spines and apertural bar, often complicated by one or more pairs of avicularia entering into the structure) in a secondary aperture; the third, again often complicated with avicularia, in a general immersion of the zoœcia beneath interzoœcial walls. The secondary aperture may be prolonged after the manner of a tubular fossil (an interesting case of a primitive method revived); but in some lineages the rims of the secondary apertures spread, especially proximally, and, meeting with their neighbours, fuse to form a secondary front wall (lamina peristomica[2] of Jullien) above the general zoarial level. Such forms—'Steginomorphs'—though belonging to various lineages, are generally placed in d'Orbigny's genus *Steginopora*, which, thus used, is seen to be a stage in evolution instead of a genus founded on d'Orbigny's genotypes. It is inconceivable that Steginomorphs can have any evolutionary future. In extreme cases they present externally a thick crust of calcium carbonate pierced here and there by holes representing apertures and avicularia, that tend to become smaller and more choked as more calcium

[1] For these terms see Lang, 1914, Geol. Mag., Dec. VI, Vol. I, p. 6.
[2] Jullien, 1886, Bull. Soc. Zool. France, Vol. 11, p. 609.

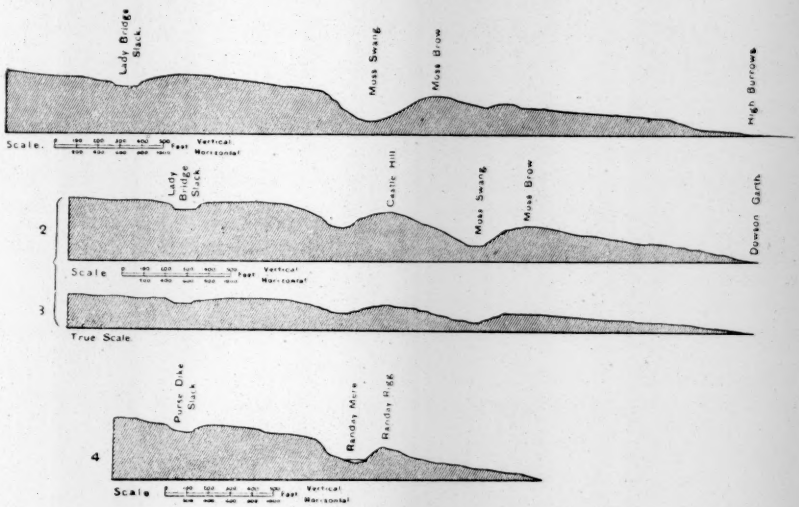
carbonate is laid down. So the cingulum of Trepostomes marks the senility of the race, and the Palæozoic Polyzoa fell a victim to the same disease as those Cretaceous forms which, owing to their calcareous skeletons, have been preserved to us to study.

VII.—Glacier Lake Channels.

By Percy Fry Kendall.

(*Concluded from the January Number, p. 29.*)

HAVING shown that the 'railway-cutting' valleys of the Goathland area exhibit anomalies of position seemingly irreconcilable with the view supported by Professor Bonney that they are vestiges of an ancient river-system that has undergone readjustments by the process of stream capture, I may now enforce the argument by exhibiting the contrast between the form and magnitude of the old and those of the new valleys in the same district.



Sections across the Overflow Channels on Murk Mire Moor.
(The datum in each case is 500 feet O.D.)

The sections figured show the general relations of the two channels on Murk Mire Moor to the valley of the Murk Esk, but for a comparison of their respective magnitudes it would be necessary to extend the slope on the right hand down to a level below 200 feet. At the 500 feet contour the Murk Esk Valley is about three-quarters of a mile wide, and the area of the section below this level over a million square feet. At 725 feet, the level at which the upper channel was begun, the area of the section is, roughly, 4½ millions of square feet. If Professor Bonney's explanation of the deserted channels be adopted it must be admitted that subaerial denudation had failed to obliterate or even to modify to any serious extent their

contours during the great lapse of time demanded for the excavation of the wide and very deep valley that is presumed to have usurped their functions.

The preservation of the contours of these deserted trenches is, next to their anomalous relations to the relief, their most marked characteristic, and it has furnished the strongest argument yet advanced for the brevity of post-Glacial time.

Whether excavated in granite, volcanic rock, slate, grit, sandstone, conglomerate, limestone, shale, or glacial materials, they show in a large proportion of cases scarcely any appreciable signs of weathering; the salient upper edges are only slightly guttered and the re-entrants at the foot of the 'batter' only rarely are filled in by the running down of the banks. Exceptions to this rule are, however, not negligible, neither are they without significance. There are in Yorkshire, as is well known, several boulder-clays distinguishable by colour, superposition, and contents; they have, as I hope to show some day more fully, a geographical distribution of great interest: (1) the lowest, the Basement Clay, is not recognizable far from the coast, though representatives probably exist in many inland situations; (2) the Purple Clay, represented in the country west of the Chalk Wolds of Lincolnshire by the Chalky Boulder-clay; and (3) the Hessle Clay. The last appears to be limited to the seaboard of Yorkshire and the Vale of York, but an equivalent stage of glaciation is recognizable in the valleys draining the eastern slopes of the Pennines from Swaledale to Airedale.

A long interval marked by widespread and drastic denudation of the earlier deposits intervened between the Hessle stage and that which preceded it, and it seems probable that a great and general retreat and readvance of the ice took place in this interval. The maximum extension of the ice at the Hessle stage was many miles, and in some areas even scores of miles, short of that attained by the ice of the Chalky Boulder-clay, besides which, in the coast region the direction of its onset was different, the north to south component being preponderant, whereas at the earlier stage the impulse seems to have been directed more from the north-east.

The limits of this readvance in Yorkshire can usually be traced with precision and clearness, in some places by well-defined moraines, in others by lake channels. The correlation of these two opposite classes of phenomena, the one an effect of deposition, the other of erosion, is comparatively easy—each forms the approximate boundary between a region in which the glacial deposits form an almost continuous mantle with the characteristic topographic features due to glaciation very fresh and complete, and areas in which the glacial deposits are reduced to a series of shreds and patches, often with long intervening spaces of driftless country. It is interesting to note that just as the Vale of York is spanned by the two great terminal moraines at York and Escrick respectively, so along the lower slopes of the Pennines two principal sets of channels trench the spurs between the river valleys. The upper set of channels is much shallower than the lower, whence it may be inferred that the extreme extension of the ice was rather "touch and go", and that a relatively

rapid shrinkage brought down to a condition of equilibrium that was maintained for a long period.

The distribution and state of preservation of lake channels is interestingly related to the several drift sheets. Within the area occupied by the ice at the Hessle stage the channels are generally in a very perfect condition, all their contours are sharp and intact; outside this area, but still within the glaciated region, are traces of half obliterated channels such as those detected by Mr. Lower Carter in the valleys of the Don and Dearne. Finally, in the area that altogether escaped the ice invasion these anomalous valleys are, I believe, entirely absent, a fact that finds no explanation in Professor Bonney's courageous hypothesis.

The facts I have set forth appear to me to render it in a high degree improbable that the channels on Murk Mire Moor can be of any great antiquity—certainly not deserving even the qualified and indefinite reference to "post-Jurassic, if not post-Cretaceous"; and the fact that, like other "certain channels", of which I have seen many hundreds, they are not filled with, or even occupied by, glacial deposits, while the great adjacent valleys of the Esk and Murk Esk contain enormous accumulations of boulder-clay and glacial gravels, seems incompatible with their existence in pre-Glacial times. Whatever the agent that deposited the boulder-clay, whether, as I believe, it was moving land-ice, or whether, as Professor Bonney at one time thought, it was an ice-encumbered sea, it is hard to understand how channels far below the elevation reached by the Drift deposits in the neighbourhood could, if pre-existent, have escaped an infilling of glacial stuff. Mr. Bernard Smith has remarked that some channels are actually excavated in the drift deposits themselves, which seems decisive, for, to adapt an illustration of Hugh Miller's, the graves cannot be older than the graveyard.

I now return to an argument employed in the first portion of this communication, namely, that based upon the systematic arrangement of the channels.

Cleveland is only one of many districts in which channels of the same type have been detected. At the risk of prolixity I must mention several: the Pentlands and Lammermuirs (1)[1]; Cheviots (2); the Wansbeck and Coquet (3); Tyne, Wear, and Tees (4); the Cross Fell escarpment (5); Swaledale; Wensleydale; Nidderdale; Wharfedale, and Airedale (6); the Hambleton Hills; the lower slopes of the Pennines from Masham to Tadcaster (7); the basins of the Don and Dearne (8); the Yorkshire Wolds (9); the Lincolnshire Wolds (10); Black Combe (11); the Forest of Bowland, East

[1] (1) Kendall & Bailey, Trans. Edin. Roy. Soc., vol. xlvi, pt. i, No. 1, 1908; (2) Kendall & Muff, Trans. Edin. Geol. Soc., vol. viii, 1903; (3) Smythe, Trans. Nat. Hist. Soc. Northumberland and Durham, N.S., vol. iii, pt. i, 1908; (4) Dwerryhouse, Q.J.G.S., vol. lviii, p. 572, 1902; (5) Kendall, *Naturalist*, 1912; (6) Jowett & Muff, Proc. Yorks. Geol. Soc., vol. xv, p. 193, 1904; (7) Kendall, Brit. Assoc. Rep., 1896; (8) Carter, Proc. Yorks. Geol. Soc., vol. xv, p. 411, 1905; (9) Kendall, ibid., p. 493; (10) Kendall and Carter, Proc. Geol. Assoc., vol. xix. p. 114; (11) Smith, Q.J.G.S., vol. lxviii, p. 402, 1912; (12) Jowett, Q.J.G.S., vol. lxx, p. 199, 1915.

Lancashire (12); the western edge of the Pennines from Rochdale to North Staffordshire, besides many districts in the North of Scotland.

I have personally examined the great majority of these to the number of several hundreds of individual channels and on lines of country extending to much more than a thousand miles. When these are plotted upon or are compared with the maps wherewith various authors have illustrated their conclusions (deduced from other classes of facts) respecting the course of the old ice-sheets, it is found that with few exceptions the channels are in the positions that would, upon such a theoretical basis, be assigned to channels draining lakes dammed up by the ice-margins. More than this, they exhibit a consistent fall towards the ice-free country. To regard this correspondence as merely fortuitous would surely be to rack "the long arm of coincidence" to dislocation point. One may start from Edinburgh and follow an early continuous succession of channels (not, however, of the same period), all sloping in the line of route, almost to the Wash, and if, as I suspect, the through-valley at the common source of the Little Ouse and the Waveney at Lopham's Ford, near Diss, be an overflow channel from the time when the Hessle Clay ice-front stood about Cromer, then the final release of the East Coast drainage must have been by the Straits of Dover.

To such an orderly and consistent system of drainage I know in all the areas enumerated but one unexplained and at present unexplainable exception, namely, the channel at Moor Close Plantation, Robin Hood's Bay. It is a depression quite shallow and innocent-looking at the upper end, but rapidly deepening into an extremely fine gorge. By the irony of fate, not only did this escape my scrutiny when working over the Cleveland district, although I crossed its evanescent upper end several times, but, oddly enough, Professor Bonney's itinerary indicates that he traversed its length, yet neither he nor I noticed that *it slopes the wrong way* and outfalls below the level of any possibly related system.

I summarize the principal objections to Professor Bonney's explanation of these remarkable channels as relics of a very ancient drainage system possibly antedating the Cretaceous period :—

1. Their restriction to the glaciated parts of our country.
2. Their 'railway-cutting' contours prove them to have been produced by large volumes of water.
3. The evidence of their production at a very recent epoch.
4. The way in which they traverse watersheds and their indifference to the geological structure of the country.
5. The continuity of the direction of their 'fall' through wide tracts of country.
6. The discontinuity of the slope where wide gaps occur in the sequence.
7. The occurrence of aligned sequences along the face of escarpments and along *both* sides of a river valley.
8. The occurrence of many parallel channels trenching a single spur.
9. Their occurrence in glacial deposits, though this goes more against the date than the mode of formation.
10. The rarity of any infilling of boulder-clay.

On the contrary hypothesis that these channels were produced by the outflowing waters of temporary lakes upheld by an ice-barrier, all these phenomena find an explanation, and the lakes themselves could in most cases have been predicted from the positions of the ice-margins that were deducible from other classes of evidence.

I do not overlook the fact that there are two fundamentally antagonistic explanations of the 'Drift' phenomena—the Land-ice theory and the 'Great Submergence', but whichever of these interpretations be the right one, neither is compatible with the 'river-trespass' hypothesis. On the other hand, I have long thought that the study of these "certain channels" did administer the merciful and much needed *coup de grâce* to the 'Great Submergence'.

REVIEWS.

I.—Geology of To-day: a popular introduction in simple language. By J. W. Gregory, F.R.S., D.Sc. 8vo; 328 pp., 26 plates. London: Seeley, Service & Co., Ltd., 1915. Price 5*s.* net.

THIS is one of a series, "The Science of To-day," intended to be at once advanced and popular: advanced in the sense of being abreast of the latest facts and theories, popular as being intelligible to those unfamiliar with technical modes of expression. "Geology," as the author fully recognizes, is a big mouthful; "a full digest of modern geology would be impossible in the space of a book of this size, and it would also be comparatively useless to a general reader." This being so, it is surprising that the author or the editor, if there be such a person, should have weighted the subject by the inclusion of palæontology, by which we do not mean such account of "The Age of Trilobites", "The Age of Graptolites", and so forth, as is contained in "Part III, Historical Geology", but rather the more biological aspect of the science that is headed "The Story of Life on Earth" and constitutes Part IV. This could easily and naturally have been expanded to form an independent volume in the series, thus leaving space for the more adequate treatment of certain strictly geological questions, which in the book as it stands are discussed too briefly or not at all. For instance, the excellent chapter on the Age of the Earth contains no reference to that most fascinating method of investigation provided by pleochroic haloes; and, even in such historical geology as there is, one would have expected a reference to the remarkable Middle Cambrian fauna described by Walcott from British Columbia and supposed also to have been detected in our own Islands.

Let it none the less be admitted that if, in "the round world and all that therein is", the author has shouldered too Atlantean a burden, he has none the less borne it right well. Professor Gregory is one of the very few geologists of the present day who has attempted, or at least attempted with any success, to carry on the traditions of the heroic age. To him the description of a new species of microscopic fossil comes as easily as the survey of an unexplored continent; the forces that fashion the globe are as familiar to his pen as those that determine the shape of a sea-urchin; from Eozoon to Eoliths *nihil*

a se alienum putat. In serious research this spreading of one's self is apt to make the result rather thin, with holes too easily picked; but in a work of the present kind comprehensive knowledge and broad views are all to the good. With this capacity Dr. Gregory combines many years' experience of lecturing to all sorts and conditions of men, and the facile touch of the ready writer. There are authors who would have been more cautious and exact, others whose style would have lent greater distinction to a narrative deserving of the highest literary skill; but taken on the whole we doubt if any man living could have made a better job of it for the public, the publishers, and himself.

A few improvements may be suggested. The relation of fiords and foldings to the rotation of the earth (p. 153) is expounded more securely than in the author's recent book on the subject, but is far too condensed for the general intelligence. The statement on p. 307 that the sub-Crag implements prove the presence of pre-Glacial man in this country is not very easily reconciled with the conclusion (p. 317) that "the geological history of man is confined to the Pleistocene Period", and that palæoliths are not likely to be found below the Boulder-clay; Dr. Gregory may be right in claiming that much of the Red Crag has been redeposited ("when" is another matter), but can he claim the whole of the Norwich Crag series as Pleistocene? Few, even amongst the most mechanistic of philosophers, will be found to agree that "all the definitions of life and of vitality apply to the more complex forms of crystal growth" (p. 234); perhaps Dr. Gregory does not sufficiently realize that life is a property, not of a certain form of matter, but of an organism. If the wind that rounded the grains and cut the pebbles of the Torridon Sandstone was dry, its dryness may have been due to cold or to passage over an ice-field; we cannot "safely conclude that the North Atlantic was not then in existence" (p. 194). In *Dinotherium* it is not the canines but two incisors of the lower jaw that are bent downward (p. 279). On p. 192, *Atikokamia*, from a Lower Eozoic limestone in Canada, is accepted as a fossil, but there are respectable geologists who regard it as of inorganic origin. Dr. Gregory kindly gives the etymology of generic names: he may like to note that the Greek for a beast is *θήρ*, for moss (or mossy seaweed) *βρύον*, = bryon not brion; that *Megalania* does not mean the big butcher, but is derived from *ἠλαίνω*, I roam; that "bent-jaw" is *Camptognathus*, but that the name he wants is *Compsognathus*, meaning "elegant jaw". "Mont Pelée" is a false concord. The English grammar also has suffered, probably from too rapid proof-reading.

The illustrations deserve a word of praise, but it should have been pointed out that the setting of Karl Hagenbeck's reproductions of extinct saurians is, from the nature of the case, not so appropriate as the backgrounds which Miss A. B. Woodward has given to her vigorous sketches of similar monsters. More reference might have been made in the text to some of the plates. The striking frontispiece —a statue of Agassiz pitched head-first through a stone pavement— will help to sell the book, but we can find no further reference to it and no explanation except that some-one or some-thing "upped with

his heels". Does the public realize that in Californian, unlike Scottish, universities earthquakes are more usual than undergraduate "rags"?

One does not look to a book of this kind for original observations or ideas, and it is in fact difficult for a reviewer whose knowledge is less exhaustive than that of Professor Gregory to decide when an opinion is taken from elsewhere, or when it has just left the writer's fertile brain. The comparison of the Old Red Sandstone to the shingle rivers of New Zealand (p. 204); the solution of the difficulty in correlating American, British, and Scandinavian glaciations by a bold denial of any synchronism at all (p. 231); the "explanation of the simultaneous extinction of many different kinds of animals" as due to a reduction in their rate of breeding "by slight changes in climate and food-supply that occurred at periods of great geographic change" (p. 293): to select these ideas as novelties may be only to expose one's lack of learning. Fortunately the knowledge of every man, even in his own science, is always less than his ignorance; so that the most learned geologist may well profit by a reading of this popular summary.

II.—Stegocephalia of Senekal, O.F.S. By Dr. E. C. N. van Hoepen, M.I.

THE material described in this paper is of very great importance, because it represents the only satisfactorily preserved large rachitomous Stegocephalian of Upper Permian age yet found. Dr. van Hoepen's excellent description is unfortunately marred by his unsatisfactory illustrations. These are rather poor half-tone blocks of photographs and, as always, fail to show the really interesting structural details. *Myriodon senekalensis*, as the form is called, is a large animal of a flattened body form, with short and rather feeble limbs. The skull is only partially preserved, the important occipital region being largely missing. The exoccipital and basi-occipital appear to be extremely similar to those of *Eryops*, but it seems to the reviewer that the bone described as the basisphenoid is really only the posterior end of the parasphenoid, from which it is said to be indistinguishable. In *Eryops* the basisphenoid is a very spongy bone, whose lower and lateral surfaces are completely sheathed by the parasphenoid, which even forms a large part of the basipterygoid processes, the cores of which are, however, formed by the cartilage bone. In a Triassic type near *Capitosaurus*, and apparently in that animal itself, the basisphenoid is only represented by a small very spongy ossification round the sella turcica, and the pterygoids unite by suture with the edge of the flat expansion of the back of the parasphenoid. Judging from the description and figure, *Myriodon* in this region is an exact intermediate between the Lower Permian *Eryops* and the Triassic forms.

The description of the lower jaw corresponds with that which the reviewer arrived at when, through the kindness of Dr. v. Hoepen, he had an opportunity of examining it. At that time, before the real structure of the Stegocephalian mandible, as described by Professor

Williston and Dr. Broom, was known, the reviewer was puzzled by certain appearances which it is now clear are probably to be explained by the presence of a post-splenial and a precoronoid. The reviewer now knows that a post-splenial is present in '*Bothriceps*' *huxleyi*, and that the large bone interpreted by him as the coronoid in *Micropholis* is really the same bone. It probably occurs also in *Batrachiderpeton* and '*Loxomma*', though the evidence here is not yet clear. The vertebral column is similar to that of *Eryops*, and the tail is fairly long.

The shoulder-girdle has widely expanded clavicles and interclavicle, as in the large Triassic forms and in the small Permian *Trimerorachis* and '*Bothriceps*' *huxleyi*. There is a cleithrum, which, as shown in the useful text-figure, caps the scapula as it does in *Eryops*. The scapulo-coracoid is structurally similar to that of *Eryops*, but the scapular portion is far shorter and makes a much more pronounced angle with the coracoidal end. The reviewer remembers seeing a suture between the precoracoid and the coracoid, and may perhaps mention here that he owes to the generosity of Professor Case a young scapula of an Eryopid which shows that the precoracoid was a separate bone forming part of the glenoid cavity, just as in *Deinetrodon*. The glenoid cavity has the peculiar screw shape common to primitive reptilia and Stegocephalia.

The bones of the fore-limbs are generally similar to those of *Eryops*, but the author inclines to the belief that the humerus was much less twisted. The humerus of *Mastodonsaurus*, though otherwise similar to that of *Eryops*, is less twisted and may have resembled that of *Myriodon*.

There are stated to be only two ossified carpals and only four metacarpals; as this is a point of very great importance, and as *Eryops* and *Cacops* seem to have five fingers, it is desirable that a definite statement of the evidence should be published.

The pelvis is generally similar to that of *Eryops*, the relation of the ilium to the sacral rib being the same in both: it is, however, perhaps still more similar to that of *Mastodonsaurus* when stripped of the addition of an ischium and a scapulo-coracoid with which it is provided in the familiar restoration.

The hind-limb is similar to that of *Eryops*, so far as the latter is known, but it is very unfortunate that Dr. van Hoepen has not published a figure of the well-ossified and extremely interesting tarsus with five or six tarsals of which he gives a description.

The reviewer some time ago suggested that the large Triassic Labyrinthodonts were derived from large Permian rachitomous forms, and these from the large Embolomerous amphibia of the Coal-measures; all subsequent work, both by other authors and by the writer, has tended to support this view: in particular the very interesting demonstration by Professor Williston that *Trimerorachis*, which had been generally supposed to be the most primitive of the Texas amphibia, is really a specialized secondarily aquatic type, has removed a stumbling-block and added an important new idea. The writer regards *Eryops* as on the whole a neutral and perhaps in some ways a conservative animal.

In the reviewer's opinion the evolution in the large amphibia took the following course. The amphibia were derived from unknown 'Crossopterygian' fish which, like all known members of that group, had a trunk of circular section and a somewhat depressed snout. The skull with the lower jaw formed a mass as high as wide at the neck, as in Maw's uncrushed '*Loxomma*' skull. The body was long (more than twenty-nine presacrals in *Pteroplax*?), and the tail probably even longer (*Pholidogaster* and *Cricotus*). The animals, as shown by the grooves for lateral line organs on the skull, were mainly aquatic. In Lower Permian times, whilst retaining their round body, they became largely terrestrial (*Eryops* and especially *Cacops* and allies), the lateral line grooves becoming obscure or absent.

Subsequently, for some cause of whose nature I can make no suggestion, the head and anterior part of the body began to become depressed, the process culminating in such extraordinarily flattened forms as *Cyclotosaurus*. Concurrently the animal became secondarily aquatic. Many changes in the skull are correlated with this depression; of these the most important are: (1) The gradual dorso-ventral thinning of the basiscranii, which leads to the almost complete suppression of the basi-occipital and basisphenoid, to the replacement of the single basi-occipital condyle of the early forms by the paired exoccipital condyles of later types, a process in which many stages are now known, and to the gradual replacement of stout basipterygoid processes of the basisphenoid by thin but necessarily broader expansions of the parasphenoid. (2) The gradual expansion of the interpterygoid vacuities from small slits in the Carboniferous forms to the enormous openings in *Cyclotosaurus*. Not so obviously correlated with the depression of the skull is a gradual shortening of that part of the pterygoids and of the quadrates, squamosal, etc., connected with them, which lie behind their articulation with the basiscranii. This results in the exoccipital condyles forming the extreme posterior points of the skull in many Triassic types.

The primitive Carboniferous amphibia had an embolomerous column in which the pleurocentra and intercentra are perforated discs of nearly equal size; reduction of the upper part of the intercentra and of the lower part of the pleurocentra leads easily to the rachitomous type found in Permian forms: still further reduction of the pleurocentra with a concurrent strengthening of the intercentra leads to the stereospondylous column found in the Triassic animals (there is unsatisfactory evidence in the Stuttgart Museum suggesting the occurrence of small pleurocentra in *Mastodonsaurus* and *Metoposaurus*). The clavicles of the typical Carboniferous embolomerous *Pteroplax* are flat plates with parallel anterior and posterior margins very like those of the fish *Megalichthys*. The interclavicle is a very small rhomboidal bone with a rudimentary posterior stern. In the more terrestrial Lower Permian types, e.g. *Eryops* and *Cacops*, the upper end of the clavicle is narrowed and affixed to the front edge of the scapula, separated from it, however, by the cleithrum, and the interclavicle becomes proportionately larger. In the Triassic forms, in correlation with the depressed form of the head and anterior part of the body and probably with the aquatic habits, the lower end of the

clavicle and the interclavicle become enormously expanded into the great bony plates so familiar in *Metoposaurus* and other types. The upper end of the clavicle, however, retains the slenderness and lack of ornament which it acquired in the Lower Permian terrestrial stage. Beyond a reduction in size necessitated by the flattened body the scapulo-coracoid remains essentially unchanged throughout the series of changes, and the fore-limb itself is only slightly altered, being smaller and more feebly ossified in later types. If Dr. v. Hoepen is correct the number of fingers is reduced to four and the humerus becomes less twisted. Except a slight weakening no change seems to take place in the hind-leg and its girdle.

From the foregoing account it will be seen to how large an extent the evolutionary changes in the temnospondylous amphibia depend on two causes, the gradual flattening of the animal and its gradual return to an aquatic life. Study of the perfect materials in the Walker Museum, under Professor Williston's charge, and in the American Museum, have considerably strengthened my belief in the close relation of *Ceraterpeton, Batrachiderpeton,* and *Diplocaulus,* animals whose ancestors have not been connected with the temnospondyl stock since very remote times. If these three creatures do really form a morphological family, then we have direct evidence that a similar flattening and return to the water have produced identical changes quite independently in two quite distinct amphibian stocks. In any case, even if the three animals mentioned above be not related, the resemblance in structural details between *Diplocaulus* and the Stereospondyls, which is very marked, must be due to convergent evolution, because whilst *Diplocaulus* is Basal Permian the stereospondyl structure did not arise till the Trias. The occurrence of four fingers in *Myriodon* whilst *Eryops* has five is another remarkable convergence to other amphibian stocks.

We have thus direct and very strong evidence that two quite distinct groups of amphibia, separating very far back, have independently pursued similar evolutionary paths at quite different rates. We have seen that in both cases these changes can be referred back to a general flattening, and then the secondary adoption of an aquatic life. No trace of these trends can have been visible when the two lines separated, for, in one case at least, their origin must have followed the adoption of, and necessary adaptation to, a primarily terrestrial existence. This fact is only a particular case of a quite general feature of evolution, that allied stocks tend to pursue a similar course of change, the same and often striking new departures being initiated in diverse lines long after their separation, not necessarily at the same time or in the same order. Students of palæozoology have long been familiar with this fact, which is perhaps the most vital contribution to evolutionary data made of recent years, and it is interesting to see that botanists are now recognizing a similar "phyletic drift" in the subjects of their study, although zoologists and especially those whose work has dealt with the experimental study of evolutionary factors have so far paid little or no attention to it. M. H. Bergson's philosophy, so far as it concerns biology, seems to depend on a superficial and incomplete appreciation of this great fact.

The importance of *Myriodon* lies in that it provides a useful intermediate stage between *Eryops* and the Triassic forms.

D. M. S. Watson.

III.—The Economic Geology of Canada.

THE coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia are described in Memoir 53 of the Geological Survey of Canada, and those of British Columbia as a whole in a later memoir (No. 69), both by D. B. Dowling. The coal horizons range from Lower Tertiary to Cretaceous over the whole area covered by the two memoirs. In character the coals grade from lignite to true coal in undisturbed strata, and from coking coal to anthracite where the rocks have undergone considerable movement. In another memoir, No. 59, Coal Fields and Coal Resources of Canada, by D. B. Dowling, we learn that the great Dominion has by far the largest reserve of coal in the Empire, estimated at no less than 1,234,269 million tons; but most of it is lignite and brown coal, and is not available for commerce since it is as yet remote from profitable markets. Important supplies, however, occur on both the Atlantic and Pacific seaboards, and are able to compete with foreign fuel.

The Canadian Department of Mines issues a publication on "Products and By-Products of Coal", by E. Stansfield and F. E. Carter, which brings together in a compact and practical form useful information as to the methods of producing coke, gas, ammonia, and tar, from bituminous coal, and the properties and industrial uses of these materials. The deplorable war conditions in Europe have made some of these products, especially coal-tar dyes, scarce in Canada; but while the demand in Canada is not sufficient to establish this industry on a profitable basis, it is shown that the production of certain other important by-products of coal is peculiarly suitable for Canada, and the Dominion could be rendered less dependent on foreign sources of supply.

The results of the testing of six lignite samples from Alberta are given in a further publication of the Department of Mines, by B. F. Haanel and J. Blizard, an instalment of an investigation of all the coals of Canada with a view to determining their best industrial uses. The Albertan lignite is shown to be well adapted for utilization in the gas producer.

Another interesting publication of the Department of Mines is a Report on the "Salt Deposits of Canada and the Salt Industry", by L. Heber Cole. The only salt deposits at present being exploited are those located in Ontario, which occur in the Salina formation (Silurian), but saline deposits are known to exist in Northern Manitoba and the Mackenzie basin of Alberta. These may be exploited as soon as these districts are opened up by railways, and may then supply the western provinces, which have now to pay high freight rates on their salt supply. The technology of salt manufacture is exhaustively described in the second part of the report.

The clay and shale deposits of Quebec are dealt with in a preliminary report (Memoir 64, Geological Survey of Canada), by

J. Keele. Stratigraphically the clays now exploited range from the Pre-Cambrian to the Pleistocene; but while there is a lack of high-grade clays like fireclays or pottery clays, there is an abundance of material suitable for the manufacture of rough clay products. The report contains valuable chapters on the origin and properties of clay, the effects of heat in clays, field examination and testing of the materials, and on methods of mining and manufacture, written mainly for the non-geological reader.

Memoir No. 74 is "A List of Canadian Mineral Occurrences", by R. A. A. Johnston. The bulk of the book is occupied with the names of the minerals arranged alphabetically, with notes as to their occurrence under the heading of each province. The second part gives the names of provinces and their divisions in alphabetical order, with the list of minerals found in each area appended. The work is an exhaustive compendium of Canadian mineralogy.

IV.—Isostasy and Radioactivity. By George F. Becker. Bull. Geol. Soc. Am., vol. xxvi, pp. 171–204, March 31, 1915.

THE object of this paper is to draw attention to certain alleged discrepancies between recent developments in the theory of isostasy, and the age of the earth as determined by radio-active methods. Dr. Becker returns to his own method of calculating the age of a cooling earth, modified by taking into consideration radio-active supplies of heat energy. He assumes that the depth at which the temperature-gradient curve most nearly approaches the diabase curve of fusion, i.e. the depth at which rock fusion is most easily accomplished, is also the depth of Hayford's level of isostatic compensation, 121 kilometres. Taking an earth with an initial temperature at the surface of 1,300° C., he finds the age to be 68 million years, radiothermal energy maintaining only one-seventh of the present temperature gradient. If radio-activity supplies two-thirds of the earth's heat loss, then the age is 1,314 million years, and the depth at which fusion most readily occurs becomes 300 kilometres. Dr. Becker rejects such an earth as being probably incapable of volcanic phenomena.

Professor Barrell (in the papers previously noticed in January last, p. 38) makes out a strong case for the existence of an asthenosphere, extending perhaps to 600 kilometres below the level of isostatic compensation. He shows that the depth of easiest fusion must be below the level of compensation, and that it is to be looked for in the heart of the asthenosphere, that is, at a depth of about 400 kilometres. Combining this result with Becker's analysis, the age of a cooling earth becomes considerably greater than 1,314 million years, and the proportion of the earth's heat maintained by radio-activity becomes much nearer to its probable value—three-quarters, or more (Geol. Mag., February and March, 1915). Geological deductions from isostasy and radio-activity are thus easily brought into harmony, and the source of the discrepancies alluded to by Dr. Becker are at least as likely to be found in his own interpretation of isostasy as in the simple method of determining the ages of radio-active minerals based on their lead-uranium ratios.

Arthur Holmes.

V.—The Klondike and Yukon Goldfield.

A REPRINT from the *Scottish Geological Magazine* of a paper by Mr. H. M. Cadell on the Klondike and Yukon Goldfield in 1913 is included in the Smithsonian Report for 1914 (pp. 363–82). The paper is both of scientific and of economic interest. The absence near Dawson of the signs of glaciation so conspicuous to the south is explained by the extreme dryness of the climate. But for the destructive work of glaciers in the Ice Age placer deposits of gold might have been found in Canada, Scotland, or Scandinavia. At the present time mining in the Klondike needs ample capital. The various ways employed for winning the gold — including the remarkable dredging process, and the hydraulic or 'monitor' method—are fully described and illustrated. About a million pounds worth of gold was extracted in 1913. The life of the field has been stated to be very limited, but there is likelihood of the discovery of paying reefs.

VI.—The Mineral Resources of the Philippine Islands for the year 1914. Division of Mines, Bureau of Science, Manila, Philippine Islands, 1915.

THE American administration of the Philippines has naturally led to a steadily increasing exploitation of the mineral wealth of the islands. Gold is by far the most important product, silver, iron, and lead following far behind. Deposits of copper, manganese, and coal have been worked from time to time, but have fallen into quiescence during recent years. Guano is now being mined as a fertilizer, and the War has reawakened interest in the manganese ores. A brief account is given of the occurrence of copper ores, associated with andesite, in Zambales.

VII.—Lavas of Hawaii and their Relations. By Whitman Cross. United States Geological Survey, Prof. Paper 88, 1915.

THE author gives a full account of the petrography of the Hawaiian islands as far as they are known at present. While the prevalent lavas are olivine basalts, many other types are represented, notably picrite basalt, bronzite basalt, trachydolerite, oligoclase-bearing lavas (e.g. kohalaite), soda-trachyte, nepheline basalt, and melilite basalt. This association indicates that the division of rock types into 'Atlantic' and 'Pacific' facies is inappropriate, and further that alkalic and calcic magmas may be derivatives from a common source. The lavas of Tahiti, Samoa, and Réunion illustrate very similar associations. The author discusses various processes of differentiation. He declines to admit Daly's view that the more basic lavas tend to issue from lower levels than the lighter ones, and denies that the association of alkaline rocks with limestones has any bearing on the origin of the former. Beyond indicating that periods of decreased activity were favourable to differentiation, and stating his opinion that the processes appear to have acted mainly on the liquid magma, the author advances no suggestions as to the physical mechanism concerned.

VIII.—Wabana Iron Ore of Newfoundland. By A. O. Hayes. Canada, Geological Survey Memoir 78, 1915.

IN this beautifully illustrated memoir a detailed account of the stratigraphy and petrology of the Lower Ordovician oolitic iron-ores of Wabana is placed on record. An unusually complete series of analyses has been made, confirming the petrographic identification of the chief minerals present—hæmatite, chamosite, and siderite. The writer concludes that the iron-ore occurs as a primary bedded deposit in a series consisting mainly of shales and sandstones. Pisolitic iron-ores have been found in the Llandeilo of Wales by W. G. Fearnsides, who, however, has urged their probable metasomatic origin. The writer gives a summary of the occurrences of other iron-ores of similar character, and notes the varying interpretations of their mode of origin, some authors favouring original precipitation, others holding the replacement theory.

IX. Skiddaw.—In the Proceedings of the Liverpool Geological Society (xii (2), 1915), Mr. Jas. W. Dunn gives the results of many years work on Sheet No. 101 S.E. (Geol. Survey, 1 inch). He does not draw up any conclusions, so we must refer the reader to the paper for the petrology, with which it largely deals.

REPORTS AND PROCEEDINGS.

Liverpool Geological Society.

December 14, 1915.—J. H. Milton, Esq., F.G.S., F.L.S., President, in the Chair.

The following paper was read:—

"On the Igneous and Pyroclastic Rocks of the Berwyn Hills (North Wales)." By the late Thomas Henry Cope, F.G.S. Edited by Charles B. Travis.

This paper represents the results of the work of the late T. H. Cope, F.G.S., during many years, supplemented by contributions by the editor. The area described, about 150 square miles in extent, includes portions of the counties of Denbigh, Merioneth, and Montgomery. The sedimentary formations present range in age from the Llandeilo to Upper Tarannon and Llandovery, and have been subjected to cross-folding at two periods of time widely separated, giving rise to a periclinal dome which has been greatly denuded.

The igneous and fragmental rocks, to which attention has been chiefly devoted, occur at various horizons in the Ordovician sediments, and comprise acid and intermediate lavas, intrusive sheets of intermediate and basic composition, and acid and intermediate fragmental deposits. The most important pyroclastic rocks are three strongly marked bands of rhyolitic tuffs and agglomerates ("Peripheral Series"), of Upper Bala age. They are traceable most clearly on the northern and western margins of the district, and correspond to the "Ash Beds" of the Geological Survey. In the southern portion

of the area, near Llangynnog, in the Tanat Valley, four bands of spherulitic rhyolite occur, associated with acid tuffs ("Lower Tuffs"). They occupy a stratigraphic position at the base of the Bala series, and are correlated with the Snowdonian lavas of the Capel Curig–Dolwyddllen group.

On the extreme easterly margin andesitic lavas and tuffs have been extruded from local vents, of which remnants are recognized. They comprise a series of hornblende-porphyrite, pyroxene, hornblende, and enstatite-andesites, with tuffs, breccias, and agglomerates of similar composition. These lavas represent the latest phase of eruptive activity in the Berwyn area on or above the horizon of the Bala Limestone, and they are probably related to the andesitic lavas and tuffs of the Breidden Hills.

The oldest volcanic rocks of the region lie in the centre of the Berwyn anticline, near Llanrhaidr yn Mochnant (the Craig y Glyn group). They are thin flows of spherulitic rhyolites, interbedded with calcareous acid tuffs, and are petrographically similar to the Llangynnog rhyolitic series, but of much greater age. They are associated with fossiliferous Llandeilo sediments, but it is considered that they may possibly be rather of Upper Arenig age.

The intrusive intermediate series occurs only in the north-eastern and south-western corners of the district, in the valleys of Glyn-ceiriog and the Hirnant respectively. In the former locality the sill has been injected into Bala slates and grits, and overlies the middle tuff band. It is a hemicrystalline, vesicular rock, a keratophyre or soda-trachyte, composed of oligoclase-andesine felspar, pyroxene, and secondary products.

The second type forms a series of five intrusive bands, hitherto mapped as volcanic ash, in the much faulted tract south of Llangynnog. These soda-rich rocks are hemicrystalline with an original glassy base, composed of oligoclase-andesine plagioclase and subordinate pyroxene, now represented by pseudomorphs and interstitial chlorite. The structure varies from variolitic to insertal. The rocks resemble certain tholeiites, but do not correspond exactly with any rocks hitherto described, and have accordingly been provisionally termed "Hirnantite".

On the northern and westerly borders and in the central part of the district a number of basic intrusions form well-marked sills in the areas characterized by great dynamic pressure. They are well exposed in the following localities: Pen-y-bont (Llansaintffraid D.C.), Spring Hill (Pandy Glynn), Cwm Dwyll, Carnedd-y-ci (Llandrillo), Cader Berwyn and Llyn-llyn-caws, and Miltir-gerig. They are dolerites in various stages of preservation, frequently bearing analcite, and agree in many respects with the basic sills of Carnarvonshire. They are, however, exceptionally interesting by the evidence of albitization which they present, a process which has not hitherto been recorded for the rocks of North Wales. In one instance (Carnedd-y-ci) albite-dolerite is associated with quartz-keratophyre under circumstances which appear to suggest an example of a composite intrusion.

CORRESPONDENCE.

THE CARRARA MARBLE DISTRICT (APUAN ALPS).

SIR,—In reply to Professor Bonney's remarks on p. 47 of the GEOLOGICAL MAGAZINE of January, suffice it to point out (1) that the determination of the age of the crystalline schists and of the marble beds is essentially a question of palæontological and stratigraphical evidence, which, as I have shown, is absolutely conclusive, and is, moreover, universally accepted; (2) that it was neither the object nor within the available space of my paper to enter into the details of microscopical examination, the less so as this part of the subject has been exhaustively dealt with in the recent memoirs of Professor d'Achiardi, of Pisa, and of Mattirolo and Franchi of the Italian Geological Survey; (3) that the district of the Apuan Alps is pre-eminently one which, owing to its extent and complexity, requires long and patient study of the entire area, and cannot be mastered by two admittedly incomplete visits, of only a few hours each, barely beyond one point of its periphery.

C. DU RICHE PRELLER.

EDINBURGH.
January 12, 1916.

THE CRYSTALLINE ROCKS OF THE PIEMONTESE ALPS.

SIR,—In a footnote (p. 16) of my paper on the Permian formation of the Maritime and Western Alps in the GEOLOGICAL MAGAZINE of January, I mentioned that I propose to deal in a subsequent paper more fully with the crystalline schists and the pietre verdi areas, also in relation to the anti-Archæan and pro-Mesozoic views of Franchi as opposed to those of Zaccagna. In the meantime I should perhaps mention that in the most recent Italian geological maps just come to my notice the extensive crystalline calc-schist formation, which up to 1909 figured as pre-Palæozoic, has been rejuvenated to Mesozoic.

C. DU RICHE PRELLER.

EDINBURGH.
January 12, 1916.

OBITUARY.

ARTHUR VAUGHAN,

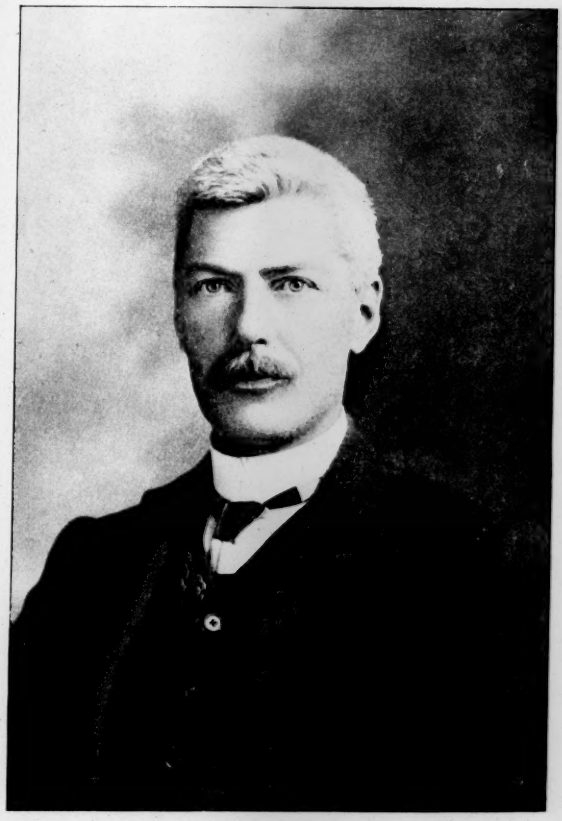
B.A. (Cant.), M.A. (Oxon.), D.Sc. (Lond.).

BORN MARCH, 1868. DIED DECEMBER 3, 1915.

(WITH A PORTRAIT, PLATE V.)

THE death at the early age of 47 of Dr. Arthur Vaughan, which took place at Oxford on December 3, removes one of the most brilliant of British stratigraphical geologists.

Dr. Vaughan was the son of the late William Vaughan, F.I.A., Actuary to the Board of Trade, and was born in London in 1868. After a highly successful career at University College School, he entered University College, London, in 1885, and there acquired his first interest in geology from the influence of Professor Bonney. In 1887 he entered Trinity College, Cambridge, with an open scholarship,



ARTHUR VAUGHAN,

B.A.(CANT.), M.A.(OXON.), D.SC.(LOND.).

1868-1915

and in his first year obtained a major mathematical scholarship. He was third Wrangler in 1890, and in 1891 obtained a First Class in mathematical physics in Part II of the Mathematical Tripos. He also obtained 1st class Honours in Mathematics in the London B.Sc. examination. These academic successes, brilliant though they were, were not considered by his teachers to do full justice to his ability.

On leaving Cambridge in 1891 he accepted a post as Senior Science Master at an Army coaching establishment at Clifton, and remained there till 1910.

His earliest papers were on mathematical physics and dealt with the earth's crust, but shortly after settling at Clifton he became acquainted with Edward Wilson, then the Curator of the Bristol Museum, and to Wilson's influence the definitely geological bent of Vaughan's main work may in a great measure be attributed. Wilson was principally interested in the Jurassic rocks, and it was to these that Vaughan first turned his attention, his earliest geological paper, "The Lower Lias of Keynsham" (1902), being written in collaboration with Mr. J. W. Tutcher.

During the years 1900 and 1901 he was engaged in the study of the splendid series of sections exposed in constructing the South Wales direct line between Filton and Wootton Bassett. The strata exposed range from the Old Red Sandstone to the Kimmeridge Clay, and include a fine section of Carboniferous Limestone. It was the study of these latter rocks which induced Vaughan to re-examine the Avon section, and led to the work with which his name will always be associated. His paper on the Carboniferous Limestone of the Bristol Area, which was published in 1905, has already become a geological classic, and as regards the wide applicability of the results, and the stimulating effect upon other workers, it may confidently be claimed that no more important piece of palæontological stratigraphy has been carried out since Lapworth's work on the Lower Palæozoic rocks.

Vaughan's results at once began to be applied by keen workers in numerous parts of the British Isles, and he himself described the Rush (1906) and Loughshinny (1908) sections in collaboration with Dr. Matley, and that of Gower (1911) with Mr. (now Lieutenant) E. L. Dixon. The above papers are principally concerned with the zonal succession of the Lower Carboniferous rocks, but deal also with the mutations of Carboniferous Corals and Brachiopods, a subject in which Vaughan quickly became deeply interested. His views on the lines of development in the case of Corals are set forth in a paper on the Avonian of Burrington Combe (1911).

The rapid growth of interest in the Carboniferous Limestone led to many problems being submitted to him, and instead of spending his spare time in healthy field work he came to be more and more confined to indoor work, which was carried out under none too favourable conditions. He was a man who never spared himself, and it is to be feared that out of the kindness of his heart he undertook much identification with which he really ought never to have been troubled. The duties of an Army tutor are also of a very exacting character, and all this hard work began about 1908 seriously to affect his health.

In 1905 he became Secretary of the British Association Committee for the investigation of life-zones in the British Carboniferous rocks, and drew up a series of important reports. Particular attention may be directed to those of Winnipeg (1909), Sheffield (1910), and Manchester (1915). In the Winnipeg report he correlated the Carboniferous Limestone (Avonian) succession in various parts of the British Isles, and threw much light on the phasal equivalents, while that at Manchester, his last piece of work, is concerned with the shifting of the western shore-line in England and Wales during the Avonian period. The Sheffield report (1910) correlates the British and Belgian succession, and was the result of a visit paid to Belgium in the summer of 1909. Vaughan paid a second visit to Belgium in 1912, this time in company with a party of British geologists, and had the satisfaction of completing his Belgian work in a paper published in the Geological Society's journal last year. The importance of this work was quickly recognized by Belgian geologists, and he was elected a Foreign Member of the Geological Society of Belgium. He received the Wollaston Fund from the Geological Society in 1907 and the Lyell Medal in 1910.

In 1910 Vaughan moved to Oxford, having accepted a post as Lecturer on Geology in the University, and the charm of his personality and his marked ability as a teacher made him very popular with his students. While at Oxford his attention was particularly directed to questions bearing on the evolution of animal life, and breaking new ground he devoted much time to the study of fossil ungulates. He was also engaged on a textbook of palæontology written on somewhat novel lines, for the illustration of which Mr. Tutcher had prepared several hundred photographs. Although this is left unfinished, there is hope that it may prove possible to publish it.

Though his lighter duties at Oxford caused some improvement in Vaughan's health, it was still the cause of much anxiety to his friends. In 1914 he visited Australia with the British Association, and was able to satisfy himself that the remarkable Permo-Carboniferous strata were correctly correlated with the Artinskian of Russia. He hoped to have the opportunity of visiting Russia for the examination of these strata, and with his usual thoroughness occupied himself during the last years of his life with the study of Russian.

Probably the characteristics which impressed themselves most on the many friends who mourn his early death were his geniality and loyalty, the courage with which he stuck to his work through long years of failing health, and the remarkable grip and clear-sighted logical analysis with which he tackled any problem.

S. H. R.

List of Papers by Arthur Vaughan.

"Stress within a Sphere due to inequalities at its surface, with application to the Earth": 1897, privately printed, Taylor & Francis.

"The Corrugation of the Earth's Surface and Volcanic Phenomena": Geol. Mag., Dec. IV, Vol. I, pp. 263–70, 1894.

"Remarks on Mr. Mellard Reade's Article 'On the Results of Unsymmetrical Cooling and Redistribution of Temperature in a Shrinking Globe as applied to the Origin of Mountain Ranges'": ibid., p. 312.

"Problems connected with a Cooling Earth": ibid., p. 505.

"The Making of Mountains: A Reply to Mr. Mellard Reade": ibid., Vol. II, pp. 93–6, 1895.

"The Argument for Solidarity drawn from Ocean Tides": Proc. Bristol Nat. Soc., ser. III, vol. viii, pp. 269–73, 1899.

"Notes on the Corals and Brachiopods obtained from the Avon Section and preserved in the Stoddart Collection": ibid., vol. x, pp. 90–134, pls. i–ii, 1903.

"The Lowest Beds of the Lower Lias at Sedbury Cliff": Abs. Proc. Geol. Soc. 1902–3, p. 124; and Q.J.G.S., vol. lix, pp. 396–402, 1903.

"The Palæontological Sequence in the Carboniferous Limestone of the Bristol Area": Abs. Proc. Geol. Soc. 1903–4, pp. 100–1, 1904; and Q.J.G.S., vol. lxi, pp. 181–305, figs., pls. xxii–ix, 1904.

"Note on the Lower Culm of North Devon": GEOL. MAG., Dec. V, Vol. I, pp. 530–2, 1904.

"Note on the Brachiopods and Corals collected by Dr. Brendon Gubbin from the Carboniferous Limestone of South-West Gower, and the Zones which they indicate": Proc. Bristol Nat. Soc., ser. IV, vol. i, pp. 53–6, 1905.

"The Carboniferous Limestone Series (Avonian) of the Avon Gorge": Proc. Bristol Nat. Soc., ser. IV, vol. i, pp. 74–168, figs., pls. i–xvi, 1906.

Note on Corals in Report of the Committee on Life-Zones in the British Carboniferous Rocks: Rep. Brit. Assoc. 1906, pp. 309–11, 1907.

"A Note on *Seminula*": Ann. Mag. Nat. Hist., ser. VII, vol. xix, pp. 194–8, 1907.

"Note on the Coral-Zones of the Avonian (Lower Carboniferous)": Proc. Geol. Assoc., vol. xx, pp. 70–3, 1907.

"A Note on the Carboniferous Sequence in the Neighbourhood of Pateley Bridge": Proc. Yorks Geol. Soc., vol. xvi, pp. 75–83, 1907.

"Faunal Succession in the Carboniferous Limestone (Avonian) of the British Isles": Rep. Brit. Assoc., vol. lxxviii, Dublin, 1908, pp. 267–9, 1909; vol. lxxix, Winnipeg, 1909, pp. 187–91, 1 pl., 1910; vol. lxxx, Sheffield, 1910, pp. 106–10, fig., 1911.

"Note on *Clisiophyllum ingletonense*, sp. nov.": Proc. Yorks Geol. Soc., N.S., vol. xvii, pp. 251–5, pl. xxxviii, 1912.

"Correlation of Dinantian and Avonian": Q.J.G.S., vol. lxxi, pp. 1–52, pls. i–vii, 1915.

"The Reef Knolls of Clitheroe, Bowland, and Craven" (read at the Yorkshire Geological Society, Leeds, June 24, 1915); to be published in the Proceedings of the Yorkshire Geol. Soc. now in the press.

"Shift of the Western Shore-line in England and Wales during the Avonian Period" (read at the British Association Meeting, Manchester, 1915).

With E. E. L. DIXON. "The Carboniferous Succession in Gower (Glamorganshire), with Notes on its Fauna and Conditions of Deposition": Abs. Proc. Geol. Soc. 1909–10, pp. 72–3, 1910; and Q.J.G.S., vol. lxvii, pp. 477–567, figs. [geol. map], pls. xxxviii–xl, 1911.

With C. A. MATLEY. "An Account of the Faunal Succession and Correlation [of the Carboniferous Rocks of Rush (Co. Dublin)]": Q.J.G.S., vol. lxii, pp. 295–322, pls. xxix–xxx, 1906.

—— "The Faunal Succession in the Carboniferous Limestone of the South-West of England and Ireland: Interim Report": GEOL. MAG., Dec. V, Vol. IV, pp. 466–8, 1906; and Rep. Brit. Assoc. Adv. Sci. 1906, York, pp. 292–3, 1907.

—— "The Carboniferous Rocks at Loughshinny (Co. Dublin)": Q.J.G.S., vol. lxiv, pp. 413–74, pls. xlix–l, 1908.

With S. H. REYNOLDS. "On the Jurassic Strata cut through by the South Wales Direct Line between Filton and Wootton Bassett, Wilts": Abs. Proc. Geol. Soc. 1901–2, pp. 132–3, 1902; and Q.J.G.S., vol. lviii, pp. 719–52, figs., 1902.